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FEASIBILITY STUDY FOR DEVELOPMENT OF HOT-WATER GEOTHERMAL SYSTEMS

CALIFORNIA UNIVERSITY

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The primary use of geothermal energy to date is for the generation of electricity. However, the development and utilization of hot-water geothermal reservoirs can be for the production of electrical, as a source of fresh water, and as a means of providing space-heating and cooling. The detection of geothermal systems consists of both regional reconnaissance and local detailed evaluation. The detection and delineation of hot-water geothermal systems is relatively primitive. Case histories using a suite of detection capabilities to pinpoint drilling locations are almost nonexistent. More must be obtained and documented.

Three potential sites of hot-water geothermal systems, Point Mugu, Twentynine Palms, and China Lake, all located in California have been investigated. Geological and other data have been developed and evaluated. Recommendations have been presented for future research efforts. (Complete abstract in final report.)

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FEASIBILITY STUDY FOR DEVELOPMENT OF

HOT-WATER GEOTHERMAL SYSTEMS

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ABSTRACT

Geothermal energy is the natural heat of the earth. Naturally occurring hot-water systems are systems which contain a single fluid phase, water, that may be at temperatures far above surface boiling because of the effect of pressure on the boiling point of water. Geothermal reservoirs of the hot-water type are located in the upflowing parts of major meteoric water convection systems. They occur worldwide in the zones of the most recent and most intense geological activity. An overlay of the distribution of earthquake epicenters is essentially a crude indication of the location of geothermal resources worldwide.

The primary use of geothermal energy to date is for the generation of electricity. However, the development and utilization of hot-water geothermal reservoirs can be for the production of electrical, as a source of fresh water, and as a means of providing space-heating and cooling. The detection of geothermal systems consists of both regional reconnaissance and local detailed evaluation. The detection and delineation of hot-water geothermal systems is relatively primitive. Case histories using a suite of detection capabilities to pinpoint drilling locations are almost nonexistent. More must be obtained and documented.

Three potential sites of hot-water geothermal systems, Point Mugu, Twenty-nine Palms, and China Lake, all located in California have been investigated. Geological and other data have been developed and evaluated. Recommendations have been presented for future research efforts. An ongoing geothermal resources research program should be developed at a significant level of funding. This abundant, widespread, multipurpose natural source of steam which does not have environmental restrictions of associated sulfur dioxides, nitrous oxides or radioactive waste may represent a substantial alternative or at least supplementary source of energy for the very near future.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General

Geothermal energy is the natural heat of the earth. Temperatures in the earth increase with increasing depth. At the base of the continental crust which is at a depth of 25 to 50 km, the temperatures range from $400^{o}C$ to $1200^{o}C$. At the center of the earth (approximately 6370 km), the temperatures are probably $3500^{o}C$ to $4500^{o}C$. However most of the earth's heat is far too deeply buried to be tapped by man even with the most optimistic assumptions of technological development. Although drilling has reached 9 km and may some day reach 15 to 20 km, the depths to which heat might be extracted economically are unlikely to be greater than 10 km.

The amount of geothermal heat available ranges from approximately 10^{19} calories (equivalent to 58,000 Mw for 50 years) to 10^{29} calories depending on the assumptions and calculations that one accepts.

In 1965, White (U.S.G.S. Circular 519) calculated that the amount of geothermal heat available in the outer 10 km of the earth's crust is approximately 3×10^{26} calories, which is more than 2000 times the heat represented by the total coal resources of the world. However, most of the geothermal heat is far too diffuse ever to be recovered. Consequently, most of the heat within the earth, even at depths of less than 10 km, cannot be considered an energy resource.

Geothermal energy, however, does have potential where heat is concentrated into restricted volumes in a manner analogous to the concentration of valuable metals into ore deposits or oil into commercial petroleum reservoirs. At present, significant concentrations of geothermal energy occur where elevated temperatures are found in permeable rocks at depths

less than 3 km. The thermal energy is stored both in the solid rock and in water and steam filling pores and fractures. This water and steam serve to transfer the heat from the rock to a well and then to the ground surface. With present technology, rocks having too few pores, or having pores that are not connected, do not comprise a usuable geothermal reservoir, however hot the rocks may be.

Water in a geothermal system also serves as the medium by which heat is transferred from a deep igneous source to a geothermal reservoir at depths shallow enough to be tapped by drill holes. Geothermal reservoirs are located in the upflowing parts of water convection systems. Cool rainwater percolates underground from areas that may comprise tens to thousands of square kilometers. At depths of 2 to 6 km, the water is heated by contact with hot rock (in turn probably in contact with molten rock). The water expands upon heating and then moves buoyantly upward in a column of relatively restricted cross-sectional area (1 to 50 km^2). The driving force of these large circulation systems is gravity, effective because of the density difference between cold, downward-moving recharge water and hot, upward-moving geothermal water.

Geothermal steam is a resource that requires both large-scale (regional) and small-scale (local) features to concentrate the natural heat within a reservoir near the earth's surface. Furthermore, this resource demonstrates the importance of both regional and areal geologic, hydrologic, geochemical, and geophysical investigations and the necessity for an interdisciplinary approach for success in detection and utilization. A strong emphasis must be placed on: (1) physical phenomena; (2) properties of rocks; (3) methods and techniques for locating and developing the

resource; and (4) influence of physical conditions within the earth's crust on migration and emplacement of magma as well as convective flow patterns of geothermal heat from source to reservoir.

1.2 Purpose and Scope

This investigation has been directed toward a feasibility study for the development of hot-water geothermal systems for potential Department of Defense utilization as an energy source. The research effort has included the gathering of both scientific and engineering data.

We will review and discuss the world-wide occurrence of both known and probable sites of hot-water (water-dominated) geothermal systems particularly in relation to United States Department of Defense installations.

In the study, we will review and discuss the geological settings and the types of detection techniques that are necessary to delineate geothermal systems.

In the original research plan, we proposed to use the Coso Thermal Area, located within the instrumented test ranges of the Naval Weapons Center, China Lake, California, as a type area for the study of water-dominated geothermal systems; however, during the course of the research, we determined to investigate two other military installations because of the abundance of published data available for the Coso Thermal Area.

In summary, this study will be concerned with hot-water geothermal systems to the exclusion of other types of reservoirs. Vapor-dominated, geopressured hot-water systems, and dry hot rock and/or magma will not be included in this report.

1.3 Definitions and Conversion Factors

Length:	1 m = 3.281 ft; 1 km = 3,281 ft = 0.6214 mi; 1 mi = 1.6094 km.
Area:	1 km^2 = $10^{10} cm^2$ = 0.3861 mi^2; 1 mi^2 = 2.5900 km^2.
Volume:	1 km^3 = $10^{15} cm^3$ = 0.2399 mi^3; 1 mi^3 = 4.168 km^3.
Mass:	1 kg = 2.205 pounds; 1 pound = 0.4536 kg.
Temperature:	(^{o}C x 9/5) + 32 = ^{o}F.
Thermal gradient:	1^{o}C/km = 2.897 ^{o}F/mi; 1^{o}C/m = 0.549 ^{o}F/ft; 1^{o}F/mi = 0.345^{o}C/km; 1^{o}F/100 ft = 1^{o}C/54.5m = 18.2^{o}C/km.
Pressure:	1 kg/cm^2 = 0.9678 atm = 0.9807 bars = 14.22 psi.
Heat:	1 cal = 3.9685 x 10^{-3} BTU; 1 cal/gm = 1.80 BTU/lb.

2. OCCURRENCES

2.1 Physical Factors Controlling Occurence

Geothermal resources are restricted to certain places and particular areas of the earth's crust. The following regional geological conditions are indicative of most geothermal systems with potential energy production: 1) Late Tertiary and Quaternary volcanism; 2) recent tectonisms (active faulting and earthquakes); and 3) areas of high temperature and consequently, greater than normal heat flow. In other words, geothermal reservoirs of the hot-water type are not uniformly distributed in the earth's crust. They are located in the upflowing parts of major meteoric water convection systems. Cool rain water percolates underground from areas that may comprise tens to thousands of square kilometers. This water circulates downward 2 to at least 6 km, where it is heated by contact with hot rock (probably an intrusive igneous mass). The water expands upon

heating and moves buoyantly upward in a column of restricted cross-sectional area (1 to 50 km^2). If the rocks have many interconnected pores or fractures, the heated water rises rapidly to the surface and the heat is dissipated. If, on the other hand, the upward movement of heated water is impeded by rocks without interconnected pores or fractures, the geothermal energy may be stored in permeable reservoir rocks below impeding layers.

Geothermal reservoirs of this type are thus "hot spots" within larger regions where the flow of heat from depth within the earth averages 1½ to perhaps 5 times the worldwide average heat flow of 1.5 HFU (1 HFU = 1×10^{-6} calories per square centimeter per second). Such regions of high average heat flow commonly are zones of young volcanism and mountain building, and are generally localized near the margins of major crustal plates. These margins are zones where either new material from the mantle is being added to the crust (spreading ridges) or where crustal material is being dragged downward and consumed in subduction zones (Muffler and White, 1972). In both situations, molten rock is generated and moves upward into the crust. These pods of igneous rock provide the heat that is then transferred by conduction to the convecting systems of meteoric water.

Some large sedimentary basins not at crustal plate margins do contain large amounts of hot water, generally at depths greater than three kilometers and at times with reservoir pressures greater than hydrostatic. Such geothermal resources are known to exist along the Gulf Coast of the United States, in Hungary, and in the U.S.S.R. The relatively high temperature gradients in these areas are due to a combination of somewhat elevated heat flow and relatively low thermal conductivity.

The continental nuclei, the Precambrian shields, are particularly unfavorable for potential geothermal systems. The shields have uniformly

low heat flow, are tectonically stable, display no recent volcanism, and are composed of old metamorphic and igneous rocks of low permeability.

For a discussion of geothermal resources at temperature greater than 100°C to be relevant, we have to place a reasonable (albeit somewhat arbitrary) limit on the depth to which one might drill. Although oil and gas wells have reached 9 km, costs per foot and technological difficulties rise strikingly at depths greater than 3 km. Perhaps not coincidentally, the deepest geothermal well drilled to date reaches only 3 km. Accordingly, we have chosen 3 km as a depth limit for present consideration. It is obvious that development of a new, cheap method of deep drilling would greatly expand the area under which we might tap 100°C water. Even under the world-wide average thermal gradient of greater than 30°C per km, 100°C water is reached at only 3.5 km, and 200°C water at only 6.5 km.

Hot-water reservoirs contain a single fluid phase at temperatures that may be far above surface boiling, owing to the effect of pressure on the boiling-point of water. When brought to the surface by a well, this water in part flashes to steam (for example, 250°C water flashed to 6 bar will give 20% by weight of steam and 80% by weight of water). Vapor-dominated ("dry-steam") geothermal reservoirs, on the other hand, contain both water and steam, with steam as the continuous, pressure-controlling phase. Wells in the vapor-dominated geothermal systems produce dry or super-heated steam. Vapor-dominated geothermal systems are perhaps 1/10 to 1/20 as common as hot-water systems. If found, vapor-dominated systems can readily be exploited using existing technology. For the purposes of the following study, we shall neglect vapor-dominated geothermal systems and concentrate on possible military applications of the much more common hot-water geothermal systems.

Naturally occurring hot-water (water-dominated) systems are systems in which water may be at temperatures far above surface boiling because of the effect of pressure on the boiling point of water. For example, the Cerro Prieto Geothermal Field located in Baja California, Mexico, has temperatures of 370°C at depths of 1500 meters. In a normal hot-water geothermal field, the fluid that first enters a producing well is liquid water. This water remains entirely as liquid water as it flows up the well until the pressure has decreased enough for steam bubbles to start to form. With continuing flow upward and continuing decrease in pressure, more water boils to steam and the temperature of the mixture decreases. The expanding steam displaces the remaining water upward as the velocity of the mixture increases. In hot-water geothermal systems, therefore, only part of the produced fluid is steam and can be used to generate electricity with present technology. For example, geothermal water at 250°C will produce only about 20 weight precent of steam when the confining pressure is lowered to 6 kilograms per square centimeter, the approximate well-head pressure commonly used in geothermal installations. The steam and water at this pressure are mechanically separated before the steam is fed to the turbine. Water in most hot-water geothermal systems is a dilute solution (1,000 to 30,000 milligrams per liter), containing mostly sodium, potassium, lithium, chloride, bicarbonate, borate, sulfate, and silica.

The average potential of a geothermal well is 5 MW. Most of the known fields have reserves of from 250 to 4000 MW.

The average life time of a geothermal field is a problematic question. Known fields have produced for as long as fifty years. Since we are dealing with a geological process, the heat in most of the geothermal

systems will probably last for from 50 to 100 million years. The main problem with hot-water geothermal systems may be a lack of long term recharge water to function as a heat transfer mechanism. However, with future technological advances in reinjection techniques, this problem may also be essentially eliminated.

2.2 World-Wide

As discussed above, geothermal reservoirs having temperatures of at least one hundred degrees Celcius are restricted to near the margins of crustal plates, i.e., in the zones of the most intense geological activity. Essentially all of the island-arc and mid-ocean ridge island systems have potential sources of geothermal energy. In particular, the Pacific "ring of fire" has vast amounts of geothermal systems.

An overlay of the distribution of earthquake epicenters is essentially a crude indication of the location of geothermal resources world-wide. Another indicator is the distribution of thermal springs around the world. The most comprehensive tabulation of thermal springs was published by the United States Geological Survey (Waring, 1965).

Kiersch (19[illegible]), under contract to the Air Force Cambridge Research Laboratories prepared an excellent report on the origin, characteristics and particularly the occurrence of geothermal systems. His work will not be duplicated in this report. Other geothermal review papers have been written by McNitt (1965), Grose (197[illegible], 1972) and Jaffé (1971).

2.3 United States

Most of the Western United States, Alaska, and Hawaii have potential sources of geothermal energy. For North America, geothermal reservoirs having temperatures of at least $100^{\circ}C$ would be expected only west of the

Great Plains, although warm springs in Virginia, Arkansas, and Georgia may indicate geothermal reservoirs perhaps reaching 100°C.

Within this large region west of the Great Plains, hot-water reservoirs appear to be abundant and widely distributed. This is indicated by a) the regional geologic setting, b) the distribution of young (late Cenozoic) volcanic rocks, c) the distribution of hot springs and fumaroles, and d) regional heat flow studies.

Koenig (1970) has shown that over 90 percent of the geothermal phenomena in the United States are in 13 western states. These phenomena consist of more than 1000 warm and hot springs and fumarole localities. At least fifteen producible fields have been discovered.

2.4 Relation to United States DOD Installations

More detailed regional studies should be conducted in order to more carefully outline the potential sources of power from hot-water geothermal reservoirs all over the world. In the present study we considered four sources of input data in order to develop a first order estimate of the potential hot-water geothermal systems in the United States. That first order estimate of the potential occurrence of geothermal reservoirs is illustrated in Plate I* which is an overlay to the map of the Major Army, Navy, and Air Force Installations in the United States, map number 8205. It should be noted on Plate I that all of the Hawaiian Islands is considered to have geothermal potential and therefore appears without specific marks.

The spatial relationship between several potential geothermal systems and DOD installations in the United States are present in Appendix I.

*Copies of Plate I can be obtained at the reader's expense from the author or Geophysics Division, Air Force Office of Scientific Research (AFOSR) 1400 Wilson Blvd., Arlington, VA 22209.

The four sources of input data to the delineation of the potential geothermal areas were: 1) the comprehensive tabulation of thermal springs and fumaroles published by the United States Geological Survey (Waring, 1965); 2) the regional geologic setting with particular emphasis on the distribution of Tertiary to Recent volcanic rocks; 3) published regional heat flow studies (Roy, et al., 1968; Sass, et al., 1971); and 4) the compilation by the United States Department of Interior of their Known Geothermal Resource Areas (Announcements of these classifications have been published in the Federal Register: 36 F.R. 5626, 5627, as corrected, 36 F.R. 6118; 36 F.R. 6441, 6442; and 36 F.R. 7319, 7320, as corrected 36 F.R. 7759.).

In summary, the two maps, Plate I and map number 8205, show the spatial relationship between potential geothermal systems and DOD installations in the United States. Until much more basic data has been developed the map Plate I must serve as the initial guide for the detection of geothermal reservoirs. As noted above there is overlap or near overlap of many potential geothermal areas with DOD installations. Three of those areas of essential overlap were chosen as site studies in the present research and several others are indicated in Appendix I.

3. DETECTION AND RESOURCE EVALUATION

Detection of geothermal systems consists of both regional reconnaissance and local detailed evaluation. Regional reconnaissance involves assessment of 1) the regional geologic setting, 2) the distribution of young (late Cenozoic to Recent) volcanic rocks, 3) the distribution of hot springs and fumaroles, and 4) regional heat flow studies along with 5) the distribution of salt diapirs (which may act as heat rods"), 6) evaluation

of remote sensing data, and 7) consideration of available geothermal gradient and temperature data.

The local detailed evaluation consists of the use of both "structural" or "indirect" methods and direct methods (Hatherton, et al. 1966; Bodvarsson, 1970; Combs and Muffler, 1973). Active seismic methods, gravity surveys, and magnetic surveys all fall under the category of "structural" methods as applied to the detection of geothermal systems. These "structural" methods do not study the properties of the hot water sought, but instead investigate the attitude and nature of the host rocks. Which of itself can be important information in the total resource evaluation.

Once a geothermal anomaly is identified, a number of surface and near-surface investigations can evaluate its relative magnitude and intensity. Geophysical techniques that have proven or suggested utility, that is, direct techniques, include electrical (D.C. resistivity and telluric), electromagnetic (loop-loop, wire-loop, transient EM, audio-magneto-tellurics), microseismic (seismic ground noise), microearthquake, and thermal (gradient and heat flow). These techniques are termed direct because they can detect properties of the hot water being sought. Geochemical methods include major element chemistry (especially SiO_2 and Na-K-Ca, which can be used to predict subsurface temperatures) and isotopic analyses (O^{18}, D, C^{13}; used to evaluate hydrologic framework). Hydrologic and geologic analysis provided information on the nature of reservoir rock expected. Research needs in site evaluation are primarily on the geophysical tools. In particular, the telluric, electromagnetic and microseismic methods are in the early developmental stages as applied to geothermal reservoir evaluation.

These surface and near-surface techniques serve primarily to site exploratory drill holes to depths of up to 3 km. Such drill holes are the only way to determine the reservoir characteristics and thus evaluate the potential for power, heat, or fresh water. Data acquired from the drill holes must include the following: 1) temperature distribution, 2) pressure distribution (by packing off and performing drill-stem tests), 3) permeability, 4) porosity, 5) lithology and stratigraphy, and 6) fluid composition. A full set of geophysical logs combined with production tests will provide these data and allow evaluation of the site.

Two needs exist for data that can only be obtained from a bore hole. The first is to determine the ability of a geothermal system to produce sufficient energy over an extended period of time to be an attractive area for development. The second need is to obtain data needed to define a model of the hot water system and to perfect methods to effectively detect and delimit such a system.

The reservoir extent and capacity can be predicted from core data giving permeability and porosity. Methods of cutting and recovering reservoir state cores in highly altered friable and fractured rocks must be developed to obtain optimum data. The productive effectiveness can be analyzed by a series of pressure data and volume of fluids recovered by drill stem tests using packers to isolate discreet zones. This technique must be researched to determine effective packer materials and pressure recording devices in high temperature environments. Drilling fluids must be developed that will not create blocking of the reservoir while drilling, in order that diagnostic measurements can be obtained.

Temperature curves of the total sections above and containing the geothermal cell must be obtained within the bore hole so the geometry of the temperature distribution can be used establishing the type and extent of the energy cell. This data is vital in equating the effectiveness of near surface temperature surveys in locating the geothermal target area. Techniques of normalizing bore hole data to a pre-bore hole regime must be developed. High temperature effects on present recording devices must be understood to achieve reproducibility of these data and to allow reliable interpretation.

The recovery of drill samples of sufficient quality to study low grade alteration of the rocks above and around the heat cell is a necessity. Research on drilling media is required in order to optimize bit cooling, upward movement of cuttings in a useful size, and maintenance of safety from blowouts while not damaging the reservoir.

The measuring of the density, velocity, and magnetism of the rocks encountered is needed to more adequately model the geophysics of the geothermal anomaly so effective methods of site selection can be made.

4. USES OF GEOTHERMAL RESOURCES

4.1 Present Uses

The primary use of geothermal energy to date is for the generation of electricity. Geothermal steam, after separation of any associated water (as much as 90 weight percent of the total effluent), is expanded into a turbine that drives a conventional generator. World electrical capacity from geothermal energy in 1973 was approximately 1000 megawatts, or about

0.10 percent of the total world electrical capacity from all generating modes. Power from favorable geothermal systems is competitive in cost with either fossil fuel or nuclear power. The production of geothermal power is obviously restricted to areas where geothermal energy is found in sufficient quantity. Unlike coal, oil, gas or uranium, geothermal steam cannot be transported long distances to a generating plant located near the existing load centers.

Geothermal resources have other uses, but to date they have been minor. Geothermal waters as low as 40°C are used locally for space heating and horticulture. Much of Reykjavik, the capital of Iceland, is heated by geothermal water, as are parts of Rotorua (New Zealand), Boise (Idaho), Klamath Falls (Oregon), and various towns in Hungary and the U.S.S.R. Geothermal steam is also used in paper manufacturing at Kawerau, New Zealand, and has potential use for refrigeration. Some geothermal waters contain potentially valuable by-products such as potassium, lithium, calcium, other metals. Use of geothermal energy to desalt geothermal water itself has been proposed, and the U.S. Bureau of Reclamation and the Office of Saline Water are presently developing a pilot operation for producing fresh water from the geothermal waters of the Imperial Valley of Southern California.

4.2 Favorable Features As An Energy Source

Favorable features of geothermal energy (those especially suited to DOD energy needs are marked *) over conventional sources of energy are:

(1) the relatively low cost;

(2) the significant environmental benefit produced by avoiding essentially all of the atmospheric and most of the thermal

pollution associated with other energy sources because no solid atmospheric pollutants are emitted and no radiation hazard is involved;*

(3) the wide-spread occurrence or availability of geothermal resources;*

(4) the modular character of facilities which provides for ease in their relocation, expansion and reduction in size at any one installation;*

(5) small-scale power generation;*

(6) reliable power sources independent of supply lines;*

(7) the multiple-use or multipurpose nature of geothermal resources, that is, geothermal resources can be used for electrical power generation*, as well as water desalting*, mineral production, space-heating and air conditioning of buildings and facilities*, defrosting of runways*, etc.;

(8) since they can be self-contained power sources in "hardened" (either underground or under water) facilities capable of providing space-heating, cooling, and fresh water as well as electric power.*

4.3 Uses of Hot-Water Geothermal Resources at Military Installations

The following uses of geothermal hot-water at military installations can be envisaged.

(1) heating and air conditioning of buildings and facilities

(2) small or large scale power generation

(3) defrosting of roads and runways

(4) recreational purposes, swimming pools, baths, saunas, etc.

(5) multipurpose nature of the energy source

(6) important power sources for small or remote installations and possible back-up or emergency power systems for larger bases.

A combination of all or any of these plus other uses can be envisaged depending on the local conditions.

5. STATE OF DEVELOPMENT OF HOT-WATER SYSTEMS

5.1 General

Hot-water systems occur worldwide. The development and utilization of this type of geothermal reservoir can be for the production of electrical power, as a source of fresh water, and as a means of providing space-heating and cooling.

A hot-water geothermal system is already in production at Cerro Prieto in Baja California, Mexico. Similar reservoirs are being produced in New Zealand, Japan, and Russia; therefore, essentially all of the withdrawal techniques and power generating equipment are available for hot-water systems with temperatures above 180°C. Power generating equipment for hot-water systems with a base temperature less than 180°C have not been satisfactorily developed and demonstrated in the United States. A further discussion of the generation of power follows.

5.2 Electrical Power Generation

Generation of power from geothermal sources can be divided into three categories:

I. Generation at greater than 200°C by using steam directly to drive a turbine. Geothermal resources (both hot-water and dry steam) at these temperatures have been developed by industry at a number of localities throughout the world. If a deposit at these temperatures is detected and delineated, development can be handled by industry using available technology. DOD funded research in utilization of these high-temperature reservoirs does not seem to be necessary.

II. Generation at less than 200°C using steam directly to drive a turbine. Industry has not seriously investigated and evaluated use of these moderate-temperature fluids for geothermal generation, although theory and a small pilot plant in Kantoga suggest that such generation may be feasible. In particular, geothermal fluids at these temperatures may have considerable use in small (1-10Mw) units at isolated sites. Research is needed as the feasibility of direct generation from moderate-temperature fluids, with comparison to item III below.

III. Generation at less than 200°C using a heat exchange and a low-boiling-point working fluid. Theory and a pilot plant at Paratunka (Kamchatka, USSR) suggest that this mode of generation may be feasible and indeed superior to item II. Inefficiencies in heat exchange may be offset by gains from small turbine size. Like item II, such stations appear well suited to meet small power needs, and may be readily adapted to hardened sites.

The main research need in geothermal utilization is for evaluation of the feasibility of electrical generation (either direct or heat exchange) from fluids of 100 to 200°C. This evaluation should take the form of alternate pilot studies of small direct and heat-exchange units.

5.3 Multipurpose Utilization

Geothermal fluids have the potential of producing fresh water by self-desalination (i.e., using the contained heat to desalt the fluid, which normally contains 5,000-25,000 ppm dissolved solids. Extensive experimentation and feasibility studies are being undertaken by the Bureau of Reclamation and the Office of Saline Water. The results of these experiments should have considerable impact to the possible production of fresh water at military installations, particularly in arid regions.

Space heating is an obvious use of geothermal resources, either independently or in conjunction with production of power or fresh water. Use of geothermal resources for heating as obvious potential applications, both on a small and a large scale. Note that approximately 90,000 people at Reykjavik, Iceland utilize geothermal resources for space heating requirements.

Moderate temperature geothermal resources appear to have considerable potential for air-conditioning and refrigeration cooling. Geothermal heat is used in a lithium-bromide system to air-condition a large hotel in Rotorua, New Zealand. Such usage may have considerable small-scale use in a variety of military installations.

5.4 Detection

The detection and delineation of hot-water geothermal systems is relatively primitive and draws heavily on methods developed in connection

with the petroleum and mining industries. Case histories using a suite of detection capabilities to pinpoint drilling locations are almost non-existent. More must be obtained and documented.

Telluric, electromagnetic and microseismic methods are in the early developmental stages as applied to geothermal reservoir detection. Much research is needed using <u>all</u> of the possible detection techniques to delineate hot-water geothermal reservoirs.

6. PROBLEMS ASSOCIATED WITH GEOTHERMAL RESOURCES

6.1 General

Problems associated with the use of geothermal energy sources are:

(1) detecting and delimiting geothermal reservoirs;

(2) development of high temperature drilling and logging technology;

(3) control of well blow-outs;

(4) scaling, corrosion, and erosion of the withdrawal and power generating equipment;

(5) disposal of waste;

(6) reduction of noise levels associated with development;

(7) possible seismic effects associated with water withdrawal and reinjection;

(8) possible land subsidence, that is, if large quantities of fluids are removed from the underground reservoir, the land surface may sink;

(9) control of noxious gases, e.g., hydrogen sulfide, which may be a by-product of geothermal wells;

(10) the reinjection of unwanted effluent waters;

(11) the rejection of surplus heat;

(12) the demonstration of the feasibility of developing large quantities of desalted water;

(13) the development and demonstration of closed cycle or heat exchange generating systems; and

(14) the development of the necessary technology to accomplish each of the tasks.

6.2 Environmental Considerations

Considerable attention has been drawn to geothermal resources as an electrical generating mode that can have a relatively small effect on the environment. Geothermal energy does not produce atmospheric particulate pollutents as do fossil fuel plants, and has no potential for radiative pollution. Geothermal does share with fossil fuel and nuclear modes the potential for thermal pollution; indeed, the amount of waste heat per unit of electricity generated is higher for geothermal than for either nuclear or fossil fuel modes, owing to the low turbine efficiencies at the low geothermal steam pressures. Geothermal effluents, as well as being warm, commonly are mineralized, and present a chemical pollution hazard to surface or ground waters. Accordingly, most if not all proposed geothermal developments in the U.S.A. plan to dispose of unwanted effluent by reinjection into the geothermal reservoir.

Potential problems that are inherent in geothermal development are in large part controllable at reasonable costs. These include noise (drilling, testing, and production), gaseous emissions (particularly H_2S), and industrial scars. Intensive geothermal exploitation may cause subsidence,

either due to fluid withdrawal or to thermal contraction of rock as heat is withdrawn. Reinjection of water in fault zones should be avoided as this may increase the incidence of earthquakes, by a mechanism similar to that demonstrated for the Rocky Mountain Arsenal well.

7. THREE STUDY AREAS

7.1 Project Definition

In the original research plan, we proposed to use the Coso Thermal Area, located within the instrumented test ranges of the Naval Weapons Center, China Lake, California, as a type area for the study of hot-water geothermal systems; however as the research progressed, we determined to investigate two other military installations because of the abundance of published data for the Coso Thermal Area. The two other areas that were chosen out of the study could be the best, but again they may not have been. They were chosen for both their potential geothermal indicators and because of geographic expediency.

The first alternative area chosen to be studied was the Point Mugu and Port Hueneme, California areas. This area was chosen because of the occasional high temperature oil wells that are drilled in both the Los Angeles Basin and the Santa Barbara Channel. A logical connection of these two areas along the grain of the major geological features of the region suggested the Point Mugu area as a potential hot water geothermal area. As can be seen from the data presented and discussed later this does not appear to be the case.

The Marine Corps Base at Twentynine Palms, California, was the second alternative area that was chosen. The primary geologic features on which this decision was made are the two very young and almost totally

unweathered volcanic craters, Pisgah Crater and Amboy Crater, with their associated extensive lava flows. Very hot, greater than [illegible]°C, water wells that have been drilled in the Twentynine Palms area also provided additional supportive information.

In this study, we review and discuss the geological settings and existing data that might be useful in the detection and delineation of potential hot-water geothermal systems on these three military installations.

7.2 Point Mugu Site

7.2.1 Introduction

The areas under investigation, the Naval Air Missile Test Center Point Mugu and the Naval Reservation near Port Hueneme, lie within the area known as the Oxnard Plain on the coast of California. The Oxnard Plain is bordered on the west by the Pacific Ocean and extends northward from Point Mugu to the city of Ventura. On the northeast and east the plain is bordered by the Camarillo Hills and Santa Monica Mountains respectively.

The area is, therefore, a part of the Pacific coastline of southern California. It is a moderately inhabited region with a mean annual rainfall of about 32 centimeters and a mean annual temperature of 16°C (61°F). The climatic conditions range from as low as 0°C (32°F) to approximately 39°C (103°F).

R.W. Page, (1963), in cooperation with the Department of the Navy, briefly described the geology of the Naval Air Missile Test Center Area Point Mugu, California, as part of a ground water appraisal. The geology described herein is based largely on Page's report.

7.2.2 Geology

The test center is underlain by approximately 500 meters of unconsolidated deposits consisting of marine clay, shale, silt, sand, sandstone, and gravel. These in turn are underlain by consolidated sedimentary rocks of early Miocene age and sedimentary and volcanic rocks of middle Miocene age (Durrell, 1954).

Surficial expressions of structural features are few in the Oxnard Plain area since most are masked by the unconsolidated and alluvial sediments. Page (1963) pointed out the Bailey Fault which traverses the southeast corner of the test center beneath several hundreds of meters of unconsolidated sediments.

The stratigraphy of the Point Mugu area can be separated into two broad categories, the older consolidated rocks consisting of the Vaquero, the Topanga and Pico formations. These formations are approximately 600 meters thick and consist of sedimentary and volcanic rocks. The second group are younger unconsolidated water bearing units comprised of the Santa Barbara and San Pedro formations and Recent alluvial deposits.

The consolidated rocks crop out east of the test center in the Santa Monica Mountains where Page (1963) describes the sedimentary units of the consolidated rocks collectively as sandstone, conglomerate and shale. The total thickness of the consolidated rocks as described by Kew (1924) is about 2400 meters but Page points out that they may be only about 600 meters thick beneath the test center.

The Vaqueros formation of early Miocene age is described by K[illegible] (1924) for exposures in the Simi Hills and in Santa Clara Valley. I[illegible]

these areas the Vaqueros appears to be conformable with both the Sespe Formation below and the Modello Formation above. The Modello does not overlie the Vaqueros in the area of the test site. The rocks of the formation in the Simi Valley area consist of conglomerate, sandstone, and shale and are about 550 meters thick. The strata are mainly a brown coarse quartzitic sandstone with very little shale. Durrell (1954) describes the stratigraphic position of the Vaqueros in the west end of the Santa Monica Mountains as overlying the "red epiclastic sediments of continental origin" of the Sespe and underlying the Topanga formation.

The Topanga Formation of middle Miocene crops out in the Santa Monica Mountains east of the test center. The formation consists of tan, brown and gray sandstones in places coarse grained and conglomeratic and volcanic rock of intrusive and extrusive basalts, andesites, rhyolites and associated agglomerate and mud flows. Kew (1924) describes the Topanga in the region south of the Simi Hills where the unit is about 1800 meters thick. Page (1963) has separated the volcanic rocks from the sedimentary rocks and reports a 600 meter thickness for the volcanic rocks that crop out in the Santa Monica Mountains. The Topanga, in the area under investigation, is overlain by the Pico formation.

The Marine Pico formation of late Pliocene age does not crop out in the area but has been detected through well logs (1N/21-3L1) and is about 21 meters thick beneath the test center (Page, 1963). The formation consists of marine clay, shale, and carbonaceous sandstone. Winterer and Durham (1958) describe the Pico formation in the area of

the Santa Susana Mountains where it is about 1500 meters thick consisting of light olive gray and medium bluish gray siltstone and fine grained silty sandstone containing small reddish-brown concretions interbedded with generally light colored mudstone conglomerate. In the Santa Susana Mountains the Pico interfingers with the overlying Saugus formation but in the area of the test site is overlain by the Santa Barbara formation.

The unconsolidated rocks are the water bearing units for the test center ground-water supply. See Well Logs in Table A III. of Appendix A for lithologic descriptions.

The Santa Barbara formation of Pleistocene age does not crop out in the test center area but is detected in well 1N/21W-31L1. It consists of about 240 meters of marine clay, shale, silt, sand, sandstone and gravel, (Page, 1963). The Santa Barbara is overlain by the San Pedro formation.

The San Pedro formation of early Pleistocene age shows up in well logs (1N/21W-31L1) and crops out in the Camarillo Hills. The formation is about 82 meters thick and consists of yellowish-brown to gray silt, sand, and gravel and contains marine fossils. The San Pedro formation is known to be penetrated by numerous wells and yields water freely to many of them (Page, 1963).

7.2.3 Existing Data

The water bearing deposits in the vicinity of the test center vary in thickness from about 242 meters (1N/21W-32A1) to about 450 meters (1N/21W-31L1) along the coast (Page, 1963). The well locations, water temperatures and geologic well logs are presented in

Appendix II-A in tables AI, AII, and AIII, respectively. A log of well 1N/21W-27F1, 2.5 kilometers north of the test site shows bedrock at a depth of 248 meters.

Data from the California Department of Water Resources shows that no well logs indicate abnormal water flow. According to Page (1963), except for local sea-water encroachment there is no evidence of movement of ground water to the Oxnard Plain from sources other than precipitation that feeds local drainage streams.

Sea water encroachment in the vicinity of Port Hueneme has resulted in the destruction of wells 1N/22W-29A1, 29A2 and 29C1 that yielded salty water (Page, 1963). Well 1N/22W-29A2 had a chloride content of only 41 ppm in 1947 so it is inferred that encroachment has occurred since that time. A high chloride content for well 1N/22W-28B1, 850 ppm, was measured in May, 1958. Samples on well 1S/21W-4E1 since 1949 indicate an increase in chloride from about 300 ppm to more than 5,000 ppm in 1953 and about 12,000 ppm in 1958. (It is believed by Page that contamination could have caused the high chloride content detected in 1948 because of faulty equipment.)

The chemical quality of the ground water in the test center area differs with depth and locally sea water has intruded the ground water body. (See Table AIV of Appendix II-A). A study of E-logs by Page revealed that the water bearing deposits could be divided into three distinct zones: (1) a shallow zone extending from the water surface to a depth of approximately 45 meters in which the water is salty, (2) an intermediate zone 45-300 meters below land surface in

which the water is brackish; (3) a deep zone 300-450 meters below land surface in which the water is salty.

Water temperature analysis does not appear to have been the concern of previous studies on the hydrology of the area as data is sparse. The temperatures available on various wells however, indicate a variability between 30°C, and 24°C. The majority of available temperatures were about 19°C (see Table AII of Appendix II-A).

7.2.4 Research Needs

The geology and the existing data for the Point Mugu are not particularly encouraging as far as the potential for a hot-water geothermal reservoir in the area. However, this lack of thermal manifestations may be caused by the encroachment of cold sea water in the subsurface. Nevertheless, we would not recommend additional research in this area in the immediate future.

7.3 TWENTY-NINE PALMS SITE

7.3.1 Introduction

The Twentynine Palms Marine Corps Training Center occupies a portion of the southeastern Mojave Desert region, California. The nearly 2500 square kilometers encompassed by the reserve lies almost entirely between 115°45' and 116°30' west longitude and 34°15' and 34°45' north latitude. The area includes within its boundaries the Bullion Mountains, parts of the Sheep Hole and Lava Bed Mountains, and portions of the Dale, Twenty-Nine Palms, Bessemer, Lavic, Bristol, Ames and Surprise Valleys.

The southeastern Mojave Desert is an arid, very sparsely inhabited region with a mean annual rainfall of 8.9 centimeters and a mean annual temperature of 20°C (68°F). The climatic conditions, however, are extreme, ranging from over 46°C (115°F) in the summer months to as low as -7°C (19°F) in the winter months. The major portion of the annual precipitation occurs during the period of November through April; the infrequent occurrence of thunderstorms during the rest of the year accounts for the remainder of the precipitation and the total surface runoff.

The mountains and valleys of the region are the topographic expression of the Basin and Range type of fault system established sometime during the Tertiary. The fault system consists of a series of right lateral normal and high angle reverse faults, uniformly trending in a northwesterly direction. Deep canyons have been carved into the upthrown fault blocks through the action of periodic runoff. Most of this infrequent storm runoff is absorbed into the semicircular alluvial fans established at the mouths of the canyons, and very little of it reaches the playas which have formed in the valley floors (Troxell and Hoffman, 1954).

The area is characterized by internal drainage and a lack of perennial streams. Some springs, however, do flow all year round; they, along with a number of wells which have been drilled on the base, supply enough water to meet the demands of the Training Center.

The first in depth research of the Mojave Desert Region was undertaken by D. G. Thompson from 1917-1921, and resulted in a geologic, geographic and hydrologic study, published in 1929. This remained the only geologic work regarding the major portion of this area until 1954, when the California Division of Water Resources published a ground water study of the Colorado River Basin which included a geologic reconnaissance map. There are basically two publications on the geology of the area, (1) a geologic report and reconnaissance map by Kupfer and Basset (1964); and (2) T.W. Dibblee's geologic maps, which cover most of the area in detail, and from which most of the geology for the present study was adapted. The geologic contributions of Miller (1938) and Gardner (1940) touch only on the fringes of the marine reserve and probably on areas of doubtful value for geothermal prospecting.

Hydrologic studies of the Twentynine Palms Marine Reserve were undertaken for several successive years in the late 1950's and early 1960's, under the auspices of the Department of Defense. Dyer (1960), Weir and Dyer (1961), and Riley and Bader (1961) published U.S.G.S. open-file reports containing yearly data on chemical analyses, core logs, and general ground water levels and conditions. These works will be valuable aids in the determination of possible areas for exploration for geothermal resources. The remaining source of data on water wells existing on the reserve were the well records of the California Department of Water Resources, Los Angeles Division.

7.3.2 Geology

A striking pattern of fault-bounded northwest trending mountain ranges and valleys suggests extensive Cenozoic tectonic activity within the southwest Mojave Desert region. The Basin and Range type, high angle normal and reverse faulting has caused secondary, relatively minor folding. Pre-Cretaceous structural features of the region were obliterated by the Late Mesozoic igneous intrusions and by the extensive early Cenozoic erosion and later Cenozoic faulting and tilting Kupfer and Bassett (1964).

Kupfer and Bassett (1964) divide the rocks of the southeastern Mojave Desert into three groups according to their inferred age: namely the "pre-Tertiary," the "older Cenozoic," and the "younger Cenozoic" rocks. The first and oldest group, the pre-Tertiary rocks, is composed entirely of volcanics and sedimentary rocks; the third group consists of volcanics and sedimentary rocks, as well as recent unconsolidated gravels, alluvium, and playa deposits.

The pre-Tertiary rocks within the bounds of the Marine reserve range in age from Precambrian through Cretaceous. Consisting of crystalline rocks of plutonic and metamorphic origin, the pre-Tertiary rocks provide the bulk of the main mountainous area, and may be considered the basement complex upon which rest Tertiary and Quaternary material. These crystalline rocks are believed to underlie the desert basins at depths, as well, but covered with younger sediments derived from erosion of the surrounding mountains.

By integrating information obtained from both Dibblee (1966; 1967a,b,c) and Kupfer and Bassett (1964), three types of metamorphic rocks can be recognized in the area: quartzite, limestone or dolomite marble, and rocks of questionable plutonic or metamorphic affinities. The rocks are exposed

mainly in the southern Bullion Mountains and points east, but this probably does not reflect their true distribution; the more northerly ranges and desert basins are predominantly covered by Tertiary volcanics and unconsolidated sediment.

Metamorphic rocks are relatively rare within the reserve. The "gneissic metamorphic rocks" described by Kupfer and Bassett (1964) incorporate not only true gneisses, but migmatitic intermixtures of metamorphic and granitic rock as well. These rocks occur primarily in the southeastern part of the area, and have not been studied in detail.

The ages of these rocks are questionable. Dibblee (1967c) states that the metasedimentary rocks are "lithologically similar to metasedimentary rocks of Paleozoic age" in areas west of the reserve boundaries, and thereby postulates a questionable Paleozoic age for the units. Kupfer and Bassett (1964) suggest that the metamorphic rocks of the desert region are of Precambrian, Paleozoic, and Mesozoic age, but none of the metamorphic rocks within the area of this reconnaissance have been accurately dated.

Although no definitive studies have been made of the plutonic rocks of the area, geologic reports on the fringing terraine, together with Dibblee's maps of a large portion of the area in question, suggest that the main mass of plutonic rock consists of light to medium gray, hard, resistant, massive, medium to coarse grained, generally porphyritic biotite quartz monzonite (Dibblee, 1967a,b,c). Locally, a younger, dark gray to black, massive, hard, medium to coarse grained hornblende-diorite or gabbro occurs as masses within the biotite quartz monzonite, and between it and an even younger quartz monzonite. The quartz monzonite forms a small stock intrusive into the biotite quartz monzonite and hornblende diorite.

The age of the biotite quartz monzonite and hornblende diorite is probably Mesozoic; the quartz monzonite is definitely Mesozoic, presumably Cretaceous.

Of some note is an iron-stained biotite quartz monzonite, lithologically identical to the biotite quartz monzonite, but stained dark brown from iron oxides, presumably through the action of hydrothermal agents. The stained monzonite occurs over a significant section of the southeastern portion of the area, where it is commonly found in contact with the "gneissic rocks" of Kupfer and Bassett (1964).

Dike rocks within the area are quite common, forming swarms of parallel dikes or scattered intrusions. Varying in thickness from less than 10 meters to as great as 30 meters (Dibblee, 1967a,b,c), these finely crystalline rocks most consistently intrude the biotite quartz monzonite, and less commonly the hornblende diorite. The steeply or vertically dipping dike rocks are composed of three general types: Dioritic to andesitic (mafic) dikes, felsitic dikes, and granite porphyry dikes. The age is probably Mesozoic (Dibblee, 1967c).

The older Cenozoic rocks consist of intrusive and extrusive volcanic and sedimentary rocks ranging from early Tertiary (Oligocene?) through Tertiary or Quaternary (Plio-Pleistocene) in age. They occur almost entirely in the northern Bullion Mountains and the Lava Bed Mountains, with small flows occurring elsewhere. A number of local and regional unconformities divide the stratigraphic sequence into discrete periods of active vulcanism followed by erosion and deposition of generally coarse detrital material.

The oldest Tertiary unit is a dacite porphyry which forms a large intrusive mass in the Sunshine Peak area. The rock is a light greenish-gray, massive porphyry, the phenocrysts consisting predominently of white plagioclase. The rock is intrusive into Mesozioc (Cretaceous?) quartz monzonite, and was probably emplaced during an early stage of Tertiary vulcanism. The dacite porphyry is assigned a tentative early Tertiary (Oligocene or Miocene?) age (Dibblee, 1966).

The volcanic and sedimentary rocks, represented particularly in the northern Bullion Mountains and Lava Bed Mountains, rest unconformably upon the uneven surface of earlier Tertiary intrusive volcanic and Mesozoic granitic rocks. The assemblage of volcanic flows, pyroclastic rocks and coarse sedimentary rocks is characterized by extreme lenticularity, intergradation, and interleaving of lithologic units. The maximum exposed thickness of the assemblage, approximately 4200 meters, occurs in the northern Bullion Mountains. The units themselves consist of rhyolitic and latitic felsites; fanglomerates of andesitic, basaltic and granitic detritus; tuffaceous and arkosic sandstone and conglomerate; andesite and tuff breccias; flow basalts; and flow andesites. The assigned age is Tertiary, most probably Oligocene or early Miocene, based on the lithologic similarity to volcanic and sedimentary rocks of Oligocene or early Miocene age in the Cady Mountains northwest of the area (Dibblee and Bassett, 1966, in Dibblee, 1967). The rocks appear to be nonfossiliferous although no definitive paleontological study has been made of this area.

The intrusive volcanic rocks occur as dikes, pods and plugs emplaced into pre-Tertiary rocks and earlier Tertiary volcanic and sedimentary focks. Dibblee (1966, 1967) proposes that the intrusive volcanics

probably fill vents and fissures through which volcanic rocks of this Tertiary assemblage erupted. The assemblage is composed of the following units: massive to flow-laminated felsites of varying local compositions; hydrothermally leached andesite porphyry occurring only in the Stedman district of the northern Bullion Mountains; a unit ranging from andesite prophyry to dacite porphyry and quartz latite porphyry; and diabasic, non-vesicular, intrusive basalt. Based upon their intrusive relationship to other Tertiary volcanics in the area, the rocks are assigned a Tertiary, probably Oligocene or Miocene age.

Approximately four kilometers south of Stedman, just within the Marine reserve boundaries, a sequence of sedimentary rocks lies unconformably upon the older volcanic and sedimentary rocks. It is in turn overlain unconformably by a rhyolitic tuff which forms the Pacific Mesa. The streamlaid sequence consists of two units: (1) a light gray, poorly bedded, lensoidal conglomerate; and (2), a light gray, fine to coarse grained sandstone. A probable Miocene or Pliocene age is assigned, based mainly upon supraposition on Oligocene (?) or Miocene (?) deposits (Dibblee, 1967). The well-indurated rhyolitic tuff forms a capping as thick as 25 meters. Apparently on the basis of supraposition, the tuff has been given a questionable late Pliocene or early Pleistocene age.

A rhyolitic felsite of similar age and lithology, lies west of the rhyolitic tuff, resting unconformably upon Tertiary volcanic and sedimentary rocks. Although probably not the same unit as the tuff, the felsite quite possibly belongs to the same period of vulcanism.

The black, massive, hard basalt forms flows and dikes in the Lava Bed Mountains. The flows unconformably overlie Tertiary tuff-breccia, and are in turn overlain unconformably by Pleistocene fanglomerates and

gravels. The age is therefore placed at late Tertiary or early Quaternary, on the basis of stratigraphic position.

The younger Cenozoic rocks and sediments range in age from Pleistocene through recent. Composed predominently of older and younger, poorly consolidated alluvial detritus, the Quaternary units have characteristically gradational boundaries. The younger Cenozoic rocks may be divided into five "classes" on the basis of age and similar lithology: (1) older valley sediments; (2) Sunshine basalt flow and craters, and basalt flows of similar age; (3) older alluvium and dissected alluvial fan material superposed on the basalt and earlier sediments; (4) Pisgah basalt flow; and (5) surficial sediments.

The older valley sediments of presumably Pleistocene or very late Tertiary age unconformably overlie Tertiary and pre-Tertiary formations. Consisting of alluvial and some lacustrine sedimentary deposits, the Quaternary rocks are weakly consolidated and slightly to severely dissected in areas which have been subject to uplift and/or deformation. The older valley sediments are composed of the following units, frequently gradational into each other: older alluvium; older fanglomerate gravel and sand of both volcanic and granitic origin; older marl and clay of playa lake deposits; a medium to coarse grained tuff of the Lava Bed Mountains; older red conglomerate; and a boulder gravel. The bulk of the sedimentary material was deposited as alluvial fans by torrential downpours in valley and former valley areas.

Basaltic lava erupted from at least three small craters northeast of Sunshine Peak to form both flow basalt and pumice. To the east, craters of similar age produced basalt flows, pyroclastics and plugs. The rocks, which locally rest unconformably upon pre-Tertiary, Tertiary and

Quaternary rocks and sediments, are considered to be Pleistocene in age. The scoriaceous lava of the craters grades outward into the flow basalt, which is commonly black, vesicular, and vitreous to microcrystalline.

Older alluvium, including dissected alluvial fan material, partially covers the basalt (conformably) and unconformably overlies older valley sediments. Derived mainly from the Bullion Mountains, the coarse fanglomerate, gravel and sand forms massive to crudely-bedded units. Locally, colors range from light-gray to black depending on the source rock of the unit. Based upon stratigraphic position, age is presumably Pleistocene.

Pisgah Crater, north of the reserve, contributed one or more basalt flows to the Lavic Lake area in the very late Pleistocene or Recent (Dibblee, 1966). The vesicular, black, microcrystalline to vitreous basalt flowed onto alluvium and partially onto the clay of the northern portion of Lavic Dry Lake.

The surficial sediments consist predominantly of unconsolidated sediments of undissected fill in valley areas and the flood plains of canyons. In large valley areas, the fill is about 30 meters thick and presumably grades downward into older alluvium or older valley sediments. Elsewhere, the fill is thinner and unconformable on older formations (from Dibblee, 1966, 1967a,b,c). The age is very late Pleistocene and Recent.

7.3.3 Existing Data

Existing data on the ground-water conditions and water wells at the Twentynine Palms Marine Corps Training Center come mainly from two sources. (1) H.B. Dyer (1960), F.S. Riley and J.S. Bader (1961), and J.E. Weir and Dyer (1959) complied reports on the water conditions at the base during several consecutive years. These studies, prepared at the request of the Department of the Navy, recorded data including temperature, chemical

analyses and depth, which are collected in Tables I-IV of Appendix II-B. J. S. Bader and W. R. Moyle (1960), and Moyle (1961), working for the California Department of Water Resources, obtained data on the water wells of the Twentynine Palms, Yucca Valley and Dale Valley areas. Although these reports are restricted to areas outside the reserve boundaries, several wells owned by the Navy were monitered. Their information is included in Tables BI to BIV of Appendix II-B.

Table BI records the locations of the wells by State Well Number, as well as well depths, available temperatures, and marks denoting accompanying logs, chemical analyses and water-level reports. Table BII includes all known water-level measurements in the area, and Table BIII includes drillers' logs of wells. Table BIV records chemical analyses of water from wells.

The major water-bearing units of the reserve are the alluvial deposits which underlie fans extending into the valleys or basins to varying depths. These units consist primarily of lenticular, intergradational beds of clay, silt, sand and gravel of Cenozoic age. Near the mountains, however, the deposits consist typically of coarse-grained, angular rock detritus (Bader and Moyle, 1960).

According to Bader and Moyle (1960), movement of ground water through the area is impeded locally by ground water barriers (presumably major faults). These barriers separate main valley areas into smaller ground water basins. The displacement of the water level across the barriers is locally as great as 75 meters (e.g. across Mesquite Dry Lake Fault).

The analyses of base and near base wells show ground water having a wide range of chemical quality. Fluoride content ranges from 0.4-100 parts per million (ppm.); chloride content from 10-725ppm.; and boron content

from 0-1.3ppm. The extremely high fluoride content of some of the wells in Mesquite and Deadman basins have rendered the water unpotable.

Although no wells surveyed in the reports record unusually high water temperatures, it should be noted (Table BI) that temperatures have been reported for only 22% of the wells in the area. Abnormally hot wells, registering 50°C and higher, have been located on privately owned land within several miles of the reserve boundaries (Donald W. Klick, personnal communication, 1972). These wells, so far unexplored, represent potential areas of investigation for possible geothermal resources.

7.3.4 Research Needs

Because of the high temperature wells located in the vicinity of the Marine Corps Training Center at Twentynine Palms, and because of the very recent Amboy and Pisgah Craters and their associated extensive lava fields, we would recommend that further research be initiated in the area to attempt to detect any potential hot-water geothermal resources that exist in the region. We will elaborate on this subject in sections 8 and 9 of this report.

7.4 China Lake Site

7.4.1 Introduction

The Coso Hot Springs area of the Naval Weapons Center at China Lake, California, was the original area that was chosen for the present study. It is a fairly rugged area with a combination of gentle valley and steep scarp terrain approximately 1000 square kilometers lying within latitudes 35° 40'N to 36° 10'N and longitudes 177° 35'W to 117° 55'W in Inyo and Kern Counties, California.

The climate is arid desert. The Naval Weapons Center is located in the northern Mojave Desert. The mean annual rainfall is about 11

centimeters and the mean annual temperature is 18°C (65°F). The temperature extremes range from a low of (-11°C) 12°F in the winter to as high as (48°C) 118°F in the summer months.

Koenig (1970) reported on a joint study at Coso Hot Springs between the U.S. Navy (Carl Austin and his coworkers) and the California Division of Mines and Geology. He stated that they conducted a detailed study, with emphasis upon geologic mapping, gravimetry, aeromagnetics, infrared mapping and other photogeologic techniques. They also used the distribution of mercury as a geochemical sensor for geothermal systems.

Koenig reported in a paper by Facca (1969) that in the Coso Hot Springs area, "Detailed magnetic traverses have resulted in the recognition of 'magnetic signatures' of the major rock types in the area, and in the probable recognition of their hydrothermally altered equivalents. Hydrothermal alteration is expressed as magnetic lows, due to destruction and removal of magnetite from the rocks by heated fluids. In some areas, in a linear zone to the west and especially south of Coso Hot Springs, magnetic lows in areas of relatively fresh granite are believed to be caused by concealed or buried hydrothermal alteration. That is, areas in which the heated fluids did not ascend to the present surface."

Furthermore, at the Coso Thermal Area, Carl Austin and his coworkers (Austin, 1966; Austin and Pringle, 1970; Austin, et al., 1971; Koenig et al., 1972) at the Naval Weapons Center have completed or are in the process of completing with other government agencies, extensive and sophisticated geologic and geophysical studies aimed at the detection of the extent and potential of the geothermal resources within the area. These Naval Weapons Center studies include: 1) preliminary surface geology with the California Division of Mines; 2) preliminary infrared

signature with the USGS and NASA; 3) detailed ground noise surveys with Teledyne-Geotech; and 4) detailed electrical resistivity with University of California-Riverside and Colorado School of Mines.

With the amount of preliminary data that has been obtained to this date, we determined to study the available data, not to duplicate it in this report, and to make recommendations about research needs.

We would point out only one criticism and that is that the large amount of existing data developed at the Coso Thermal Area should be published in readily available technical journals. Most of the data appears as Naval Weapons Center (NWC) documents and is therefore not readily available for use. Most of these NWC documents have had Carl F. Austin as the primary author (Austin, 1966; Austin and Pringle, 1970; Austin, et al., 1971; Koenig, et al., 1972).

7.4.2 Geology

Most of the geology is based on the Trona and Death Valley sheets of the Geologic Map of California. The exposed basement terrain consists of Mesozoic granitic rocks of medium-tocoarse-grained quartz monzonite, quartz diorite, etc. These plutonic rocks are related to the Sierra Nevada Batholith to the west and are the primary substructure. These older rocks were faulted and eroded to approximately their present surface relief and were later subjected to moderate Tertiary to Quaternary volcanism.

The Tertiary-Quaternary rocks reached the surface via channels rising through the Mesozoic basement rocks in the form of dikes, sills, plugs, necks, vents and craters. Volcanic rocks superimposed on the basement terrain produced Pleistocene rhyolitic, andesitic, and basaltic lava flows,

in addition to numerous scattered prominent cones, craters and domes of effusive and pyroclastic materials.

The volcanic rocks in the northwest of the area, generally southwest of McCloud Flat, consist of Tertiary andesite flows, sills, and plugs. Those volcanic rocks forming the cones, craters, domes, and their adjacent slopes in the central part of the area (Cactus Peak, Sugarloaf Mountain, etc.) consist of Quaternary lapilli tuffs, rhyolite and obsidian flows, pumice, perlite, and cinders. Pyroclastic material from the volcanic activity has also accumulated on the lower slopes and in the small basins. The extensive, rugged "lava-breaks" terrain, generally east of Coso Hot Springs, consists primarily of porphyritic andesite and vesicular basalt flows, which have been faulted along north-south trends. Faulting and later erosion of these lava flows has produced a series of step-scarps rising west-to-east from the basin containing Coso Hot Springs.

The Quaternary alluvial deposits across the survey area reach their maximum thicknesses, estimated at 120 to 200 meters, in the larger basins of McCloud Flat, Upper Cactus Flat, and the basin of Coso Hot Springs. Two smaller basins approximately 2.5 square-kilometer extent each are immediately north of Cactus Peak and immediately northwest of Sugarloaf Mountain. Other scattered small basins are common across the area with alluvial thicknesses estimated at less than 30 meters. The basins contain unconsolidated pumiceous and arkosic sands, gravels, playa deposits, windblown sand, stream wash, and other alluvial debris derived from the adjacent igneous outcrops.

The obvious surface manifestations of geothermal activity consist of exposed, discolored, mineralized, hydrothermal alteration zones. An

active fumarole belt along a six and one half kilometer arc trends southwest to northeast through the exposed hydrothermal alteration localities. This active fumarole belt passes from the Devil's Kitchen area through Coso Hot Springs. These surface manifestation zones are fault related. The predominant fault in the region is the Garlock Fault which has a similar southwest to northeast strike. It would appear that the regional tectonic patterns have produced the local structural trends and the surface manifestations. The steam venting at the surface fumaroles is moderately sulfurous, certainly corrosive, with low pressure and low flow volume.

7.4.3 Existing Data

As has been noted above, there is an abundance of geological, geochemical, and geophysical data available for the Coso Hot Springs area in a number of Naval Weapons Center documents (see, Austin, 1966; Austin and Pringle, 1970; Austin, *et al*., 1971; Koenig, *et al*., 1972).

The existing water well locations, geologic logs, and chemical analyses are presented in Appendix II-C in the Tables CI to CVI.

7.4.4 Research Needs

Although we have not seen all of the data that has been developed, we would recommend the following future studies. First, the preparation of a detailed surface geologic map. The former geochemical and geophysical survey which have been made should be completed and published in technical journals.

We would suggest the drilling of from 4 to 6 heat flow boreholes which should be no less than 100 meters total depth. These should be located using the seismic ground noise and the electrical resistivity data. At least one of the heat flow determinations should be made in a

potentially non-productive area in order to establish the magnitude of the background heat flow for the area.

Further research in the Coso area beyond those studies suggested above should be devoted to exploratory drilling to determine the extent of the reservoir as indicated by the surface measurements.

8. DISCUSSION AND CONCLUSIONS

8.1 Potential of Hot-Water Geothermal Systems

Hot-water geothermal resources are a multiple-use or multipurpose natural resource, that is, hot-water geothermal resources can be used for electrical power generation, as well as a source of fresh water; mineral production; space-heating and air-conditioning of buildings and facilities; recreational purposes, swimming pools, baths, saunas, etc.; defrosting of runways; and others.

The average electrical power potential of a single geothermal well is 5 MW. The known fields have reserves of from 250 to 4,000 MW. The average lifetime of a geothermal field is a problematic question. Known fields have produced continuously for as long as fifty years. Since we are dealing with a geological process, the heat in most of the geothermal systems will probably last for from 50 to 100 million years. The main problem with hot-water geothermal systems may be a lack of long term recharge water to function as a heat transfer mechanism. However, with future technological advances in reinjection techniques, this potential problem may also be eliminated.

8.2 Detection of Potential Geothermal Systems

Detection techniques for geothermal resources are relatively primitive, especially those applied to detection of hot-water reservoirs. Geothermal

steam is a resource that requires both large-scale (regional) and small-scale (local) features to concentrate the natural heat within a reservoir near the earth's surface.

Furthermore, this natural resource demonstrates the importance of both regional and areal geologic, hydrologic, geochemical, and geophysical investigations and the necessity for an interdisciplinary approach for success in detection and utilization. A strong emphasis must be placed on: 1) physical phenomena; 2) properties of rocks; 3) methods and techniques for detection and developing the resource; and 4) influence of physical conditions within the earth's crust on migration and emplacement of magma as well as convective flow patterns of geothermal heat from source to reservoir.

An extensive program of research is necessary to develop better geophysical, geological, hydrological, and geochemical methods of detection specifically tailored to geothermal resources. An immediate specific need is to combine and compare the existing data for a potential geothermal area with data developed from geophysical studies in order to provide information for detection purposes elsewhere. Case histories using a suite of detection capabilities to pinpoint drilling locations are almost nonexistent. More must be obtained and documented.

8.3 Evaluation and Development of Geothermal Systems

World-wide, there are only 11 geothermal areas actually producing electrical power. Of these, four (including the only area in the USA) are vapor-dominated (dry-steam) areas. Of the hot-water systems, for only one, Wairakei, New Zealand, does there exist any significant body of production data, and even this data set is inadequate. Thus, one of the

major uncertainties in the development of a hot-water reservoir is the manner in which it will behave under production. How will temperature, pressure, fluid enthalpy and production change with time? What will be the productive life of the system? How can the production be optimized? Is this type of geothermal reservoir in practice a closed system, or is there significant recharge of water and heat? Can production be enhanced by various means of reservoir stimulation?

Accordingly, there is a critical need for a pilot project to drill, produce, and monitor a hot-water geothermal system. Such a pilot project should not be constrained by any economic necessity to sell electricity, water, or heat at a profit. Such a pilot project should be instrumented, both with surface and bore hole instrumentation, to provide all the data necessary to document production history. This history will be used to test production models, predict future performances, evaluate economic and technical feasibility, and extrapolate to other hot-water areas. The area of investigation should encompass not only the upflowing plumes of hot water, but also the recharge part of the circulation system (this will involve monitor drilling for hydrologic data). Drilling within the geothermal system should be deep enough to investigate the heat source (whether magma or hot rock) and provide sufficient data to produce a reliable, documented picture of the whole natural geothermal system.

9. RECOMMENDATIONS

An ongoing geothermal resources research program should be developed at a significant level of funding. This abundant, widespread, multipurpose natural source of steam which does not have environmental restriction of associated sulfur dioxides, nitrous oxides or radioactive wastes may represent a substantial alternative or at least supplementry source of energy for the very near future.

As pertains to follow up research to this study, we recommend the following:

1) The geology and the existing data for the Point Mugu Site are not particularly encouraging as far as the potential for a hot-water geothermal reservoir in the area. However, this lack of thermal manifestations may be caused by the encroachment of cold sea water in the subsurface. Nevertheless, we would not recommend additional research in this area in the immediate future.

2) Because of the high temperature water wells located in the vicinity of the Marine Corps Training Center at the Twentynine Palms Site, and because of the very recent Amboy and Pisgah Craters and their associated extensive lava fields, we would recommend that further research be initiated in the area to attempt to detect any potential hot-water geothermal reservoirs that may exist in the region. This research should include both regional and local geological, hydrological, geochemical, and geophysical investigations in order to detect and determine the extent of any geothermal reservoir. and

3) We recommend that a detailed surface geologic map be prepared for the China Lake Site. The available geochemical and geophysical surveys should be completed and published. We would recommend the drilling of from 4 to 6 heat flow boreholes which should be no less than 100 meters total depth. These should be located using the available seismic ground noise and electrical resistivity data. At least one of the heat flow determinations should be made in a potentially non-productive area in order to establish the magnitude of the background heat flow for the area. Further research in the Coso Thermal area beyond those suggested above should be devoted to exploratory drilling to determine the extent of the reservoir as indicated by the surface measurements.

In addition, there is a need to demonstrate that the particular locations tabulated in Appendix I are in fact potential geothermal resource areas. This can be accomplished most satisfactorily by drilling one heat flow hole no less than 100 meters total depth on several of the installations listed in the colocation summary, Appendix I. We recommend that these reconnaissance heat flow holes be drilled. Furthermore, we recommend that on at least one of the potentially lower enthalphy systems such as the Twentynine Palms Site, a complete detection program be implimented.

10. REFERENCES

Austin, C.F., 1966, Selection criteria for geothermal prospects: Nevada Bureau of Mines, Report 13, Part C, Reno, Nevada, pp. 93-125.

Austin, C.F., Austin, W.H. Jr., and Leonard, G.W., 1971, Geothermal science and technology - a national program, Naval Weapons Center, China Lake, California, NWC TS 45-029-72

Austin, C.F., and Pringle, J.K., 1970, Geologic investigations of the Coso Thermal Area: Naval Weapons Center, China Lake, California, NWC TP 4878

Bader, J.S., and Moyle, W.R., Jr., 1960, Data on water wells and springs in the Yucca Valley-Twentynine Palms area, San Bernardino and Riverside Counties, California: Calif. Dept. Water Resources, Bull. 91-2, 163 p.

Bassett, Allen M., and Kupfer, Donald H., 1964, A geologic reconnaissance in the southeastern Mojave Desert, California: Calif. Div. of Mines and Geol. Special Report 83, 43 p.

Bodvarsson, G., 1970, Evaluation of geothermal prospects and the objectives of geothermal exploration: Geoexploration, v. 8, p. 7-17.

California Dept. Water Resources, 1963, Bulletin, 130:63, Vol. 5.

California Division of Water Resources, 1954, Ground water occurrence and quality, Colorado River Basin Region: Water Quality Inv. 4, 59 p.

Combs, Jim, and Muffler, L.J.P., 1973, Exploration for geothermal resources: in Kruger, Paul, and Otte, Carel (eds.), 1973, Geothermal Energy: Resources, Production, Stimulation: Stanford Univ. Press, Palo Alto, California, p. 95-128.

Dibblee, T.W., Jr., 1967a, Geologic map of the Deadman Lake quadrangle, San Bernardino County, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-488, scale 1:62,500.

----1967b, Geologic map of the Emerson Lake quadrangle, San Bernardino County, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-490, scale 1:62,500.

----1966, Geologic map of the Lavic quadrangle, San Bernardino County, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-472, scale 1:62,500.

----1967c, Geologic map of the Ludlow quadrangle, San Bernardino County, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-477, scale 1:62,500.

Durrell, Cordell, 1954, Geology of the Santa Monica Mtns., Los Angeles and Ventura Counties, in Geology of southern Calif.: U.S. Geol. Survey Bull. 170, Map Sheet 8.

Dyer, H.B., 1960, Ground-water conditions during 1960 at the Marine Corps Base, Twentynine Palms, California: U.S. Geol. Survey open file report, U.S.G.S. Ground Water Branch, Long Beach, California, 32 p.

Facca, G, 1969, Geophysical investigations in the self-sealing geothermal fields: Bull. Volcanologique, 33 (1), 119-122.

Gardner, D.L., 1940, Geology of the Newberry and Ord Mountains, San Bernardino County, California: California Jour. Mines and Geology, v. 36, p. 257-292.

Grose, L.T., 1971, Geothermal energy: geology, exploration and developments. Part 1: Colo. School of Mines, Mineral Industries Bull., v. 14, no. 6, p. 1-14.

Grose, L.T., 1972, Geothermal energy: geology, exploration and developments. Part 2: Colo. School of Mines, Mineral Industries Bull., v. 15, no. 1, p. 1-16.

Hatherton, T., Macdonald, W.J.P., and Thompson, G.E.K., 1966, Geophysical methods in geothermal prospecting in New Zealand: Bull. Volcanol., v. 29, p. 485-497.

Jaffé, F.C., 1971, Geothermal energy, a review: Bull. Ver. Schweiz. Petrol. -Geol. u. -lng., v. 38, no. 93, p. 17-40.

Kew, W.S.W., 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U.S.G.S. Bull. 753, 202p.

Kiersch, G.A., 1964, Geothermal steam: Origin, characteristics, occurrence, and exploitation: Final report Air Force Cambridge Research Laboratories contract No. AF-19 (628)-293, 204 pp.

Koenig, J.B., 1970, Geothermal exploration in the Western United States: Geothermics, Special Issue 2, v.2, pt. 1, p. 1-13.

Koenig, J.B., Garvarecki, S.J., and Austin, C.F., 1972, Remote sensing survey of the Coso Geothermal Area, Inyo County, California, Naval Weapons Center, China Lake, California, NWC TP 5233.

McNitt, J.R., 1965, Review of geothermal resources: in Lee, W.H.K., ed., Terrestrial Heat Flow: Am. Geophys. Union, Geophys. Monograph no. 8, p. 240-266.

Miller, W.J., 1938, Pre-Cambrian and associated rocks near Twentynine Palms, California: Geol. Soc. Am. Bull., v. 49, p. 417-446.

Moyle, W.R., Jr., 1961, Data on water wells in the Dale Valley area, San Bernardino and Riverside Counties, California: California Dept. Water Resources, Bull. 91-5, 55 p.

Muffler, L.J.P., and D.E. White, 1972, Geothermal energy: The Science Teacher, v. 39, no. 3, p. 40-43.

Page, R.W., 1963, Geology and Ground Water Appraisal of the Naval Air Missile Test Center Point Magu, California: U.S.G.S. Water-Supply Paper 1619-S, 40 pp.

Riley, F.S., and Bader, J.S., 1961, Data on water wells on Marine Corps Base, Twentynine Palms, California: U.S. Geol. Survey open file report, U.S.G.S. Ground Water Branch, Long Beach, California, 72 p.

Roy, R.F., Decker, E.R., Blackwell, D.D., and Birch, Francis, 1968, Heat flow in the United States: J. Geophy. Res., v. 73, p. 5207-5221.

Sass, J.H., Lachenbruch, A.H., Monroe, R.J., Green, G.W., and Moses, T.H., 1971, Heat flow in the western United States: J. Geophy. Res., v. 76, p. 6376-6413.

Thompson, D.G., 1929, The Mojave Desert region, California; a geographic, geologic, and hydrologic reconnaissance: U.S. Geol. Survey Water-Supply Paper 578, 759 p.

Troxell, H.C., and Hofmann, Walter, 1954, Hydrology of the Mojave Desert: California Div. Mines Bull. 170, ch. 6, p. 13-17.

Tucker, W.B., and Sampson, R.J., 1940, Economic mineral deposits of the Newberry and Ord Mountains, San Bernardino County: California Jour. of Mines and Geology, v. 36, no. 3, p. 232-254.

Waring, G.A., 1965, Thermal springs of the United States and other countries of the world - a summary: U.S. Geol. Survey Prof. Paper 492, 383 pp.

Weir, J.E., Jr., and Dyer, H.B., 1961, Ground-water conditions during 1961 at the Marine Corps Base, Twentynine Palms, California: U.S. Geol. Survey open file report, U.S.G.S. Ground Water Branch, Long Beach, California.

White, D.E., 1965, Geothermal energy: U.S. Geol. Survey Circular 519, 17 pp.

Winterer, E.L., and Durham, D.L., 1958, Geologic Map of a Part of the Ventura Basin, Los Angeles County, Calif.: U.S.G.S. Oil and Gas Inv. Map OM-196.

U.S. Environmental Data Service, Climatological Data: California, 1959-61, 1969-70, v. 63-65, 73-74.

11. APPENDIXES

APPENDIX I.

COLOCATION SUMMARY OF SEVERAL POTENTIAL

GEOTHERMAL SYSTEMS AND MILITARY INSTALLATIONS

I.1 Military Installations on Known Geothermal Resources Areas

STATE	NAME	MAP-8205 #
California:	Weapons Center, China Lake	5F-1
Oregon:	Kingsley Field	4C-1

I.2 Military Installations on Areas with Potential Geothermal Resources

STATE	NAME	MAP-8205 #
California:	Marine Corps Base, Twentynine Palms	6F-2
	Air Facility, El Centro	6G-1
	Twenty Second AF HQ, Travis AFB	4E-5
	Weapons Station, Concord, Calif.	4E-10
	Rio Vista Storage Area (Act. of Sharpe Army Depot)	4E-6
	Parks, Camp (IN)	4E-12
	Radio Station, Dixon	4E-13
	Sierra Army Depot	4D-1
Nevada:	Air Station (Auxiliary), Fallon	5D-2
Utah:	Utah Army Depot (Permitted to DSA)	7D-1
Alaska:	Communication Station, Clam Lagoon, Adak, Alaska; Radio Station, Mt. Moffett, Adak, Alaska; Station (Naval), Adak, Alaska	26S-1

I.3 Military Installations on Areas With Warm Springs

None

I.4 Military Installations Within 10 Km of Known Geothermal Resource Areas

STATE	NAME	MAP-8205 #
California:	Air Facility, El Centro	6G-1

I.5 Military Installations Within 10 Km of Potential Geothermal Resource Areas

STATE	NAME	MAP-8205 #
California:	Schools Command, Mare Island, Vallejo	4E-36
	Shipyard, San Francisco Bay, Mare Island Division	4E-7
Utah:	Fort Douglas (IN)	7D-5
	Tooele Army Depot	7D-6
	OOAMA HQ, Hill AFB	7D-4
Alaska:	King Salmon Airport	32Q-1
	Eielson AFB	35N-1
	Wainwright, Fort	35N-2

I.6 Military Installations Within 10 Km of Warm Springs

STATE	NAME	MAP-8205 #
California:	Obispo, Camp San Luis (IN)	4F-3

We note that the above list is not exhaustive but is complete as pertains to present knowledge of the location of geothermal resources. There will be many areas of the country which have potential geothermal resources and possible colocation with military installations. However, they are not included because they were not identified by the four criteria listed in Section 2.4. For example, the two recent exploratory geothermal wells drilled near Williams AFB, Chandler, Arizona.

APPENDIX II-A.

POINT MUGU SITE

APPENDIX II-A.

Existing Data for Selected Water Wells on or Near

Point Mugu and Port Hueneme, California

All of the wells in Appendix A and the following appendices are located and numbered according to the California state well numbering system. The state well numbering system is based on township, range, and section subdivision of the Public Land Survey. Under the system, each section is divided into 40 acre tracts lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Wells are numbered within each 40 acre tract according to the chronological sequence in which they have been assigned State Well Numbers.

Example: 1N/22W-16D4,S would be found in township 1 north, Range 22 West, Section 16, San Bernardino Base and Meridian, and would be further designated as the fourth well assigned a State Well Number in tract D.

Incomplete numbers, such as IN/22W-8A or 2N/22W-13, indicate approximate locations of wells to the extent indicated by the symbol.

APPENDIX II-A.

Existing Data for Selected Water Wells on or Near

Point Mugu and Port Hueneme, California

All of the wells in Appendix A and the following appendices are located and numbered according to the California state well numbering system. The state well numbering system is based on township, range, and section subdivision of the Public Land Survey. Under the system, each section is divided into 40 acre tracts lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Wells are numbered within each 40 acre tract according to the chronological sequence in which they have been assigned State Well Numbers.

Example: 1N/22W-16D4,S would be found in township 1 north, Range 22 West, Section 16, San Bernardino Base and Meridian, and would be further designated as the fourth well assigned a State Well Number in tract D.

Incomplete numbers, such as IN/22W-8A or 2N/22W-13, indicate approximate locations of wells to the extent indicated by the symbol.

Table A I. Locations of wells on or near Point Mugu and Port Hueneme, California.

T1 N/R22W-		Agency Supplying Well Log Data	Logs Available at Calif. Dept. Water Resources	Water Analysis, Water Levels (WA/WL)
16D1	@	SWN		
16D2	*	5003		
16D3		SWN		
16D4		5050	X	(WA)
16E1		5003		
16L1	@	SWN		
16M1		SWN		
16M2		USN		
16M3		SWN		
17B1	*	5003	X	(WA/WL)
17B2	@	SWN		
17B3		USN		
17C1	*	SWN		
17C2		SWN	X	
17D1		SWN		
17D2	*	SWN		
17G1		USN		
17F1		USN		
17J1		USN		
17J2		SWN		
17M1		No Info.		
17M2		SWN	X	(WL)
17M3	*	5050		
17Q1	*	SWN		
18A1	@	SWN		
18J1	@	SWN		
19A1	@*	2100	X	(WA)
20B1	*	SWN	X	(WA/WL)
20C1		No Info.		
20E1	*	5050	X	(WL)
20E2	*	5050	X	(WA/WL)
20G1		5050	X	
20H1		5050	X	(WA)
20H2		5050	X	(WA/WL)
20H3		5050	X	(WA/WL)
20H4		5050	X	(WA/WL)
20H5		5050		
20H6		5050	X	
20H7		5050		
20H8		5050	X	

CONTINUED

@ indicates wells that lie just outside the military boundry lines.

* indicates wells whose water levels are published in California Dept. of Water Resources Bulletin 130:63, Vol. 5, 1963.

T1N/R22W-		Agency Supplying Well Log Data	Logs Available at Calif. Dept. Water Resources	Water Analysis, Water Levels (WA/WL)
20J1		5050	X	
20J2		5050	X	
20J3		5050	X	
20K1		5050	X	(WA/WL)
20L1		USN		
20N1		SWN	X	(WA/WL)
20N2	*	5050	X	(WL)
20R1	*	SWN		
20R2		SWN		
21E11		5050	X	(WA/WL)
21E12		5050	X	(WA/WL)
21F1		5050	X	(WA)
21F2		5050	X	(WA/WL)
21F3		5050	X	(WA/WL)
21L1	*	5050	X	(WA/WL)
21L5		5050	X	(WA)
21L6		5050	X	(WA)
21N1		SWN		
21E5		5050	X	(WA)
21E6		5050	X	(WA)
21E10		5050	X	(WA)
21E7		5050	X	(WA)
21E8		5050	X	(WA)
21E9		5050	X	(WA)
21C1		SWN	X	(WL)
21E1		No Info.		
21E2		USN		
21E3		USN		
21E4		5050	X	(WA)
21M1		5050		
21M2		5050		
21L2		SWN		
21L3		5050		
21L4		5050		

Well logs for the following wells can be obtained from the California Dept. of Water Resources although not indicated on filed data cards at the agency.

T1N/R22W-

21B1
21B3
21J2
21J3

Notes: If the symbols (WA) or (WL) are listed for a particular well this indicates that either water analysis or water levels information is available, (WA/WL) indicates both are available.

Agency Code

USN ....United States Navy.
SWN ....Official State Well Numbering System.
5050....Official State Well Numbering System, State Agency.
5003....Official State Well Numbering System, Federal Agency.
2100....Ventura County Flood Control District, Federal Agency.

Table A II. Water temperatures from typical water wells on or near Point Mugu and Port Hueneme, California. Data from California Department of Water Resources.

IN/R22W-	Dates	Temperatures, °F
16D2	4-16-58	69
	6-23-61	67
16D4	11- 2-64	68
	12- 3-64	68
16E1	5-21-58	68
	4-29-64	68
17B1	5-13-58	70
	6-30-61	67
	5-15-69	66
17C1	5-13-58	68
	6-30-61	68
	5-28-68	66
	5-14-69	66
17C2	12-18-61	70
17D2	5-13-58	68
	6-30-61	66
	5-28-68	66
	5-15-69	64
17J1	5-21-58	68
17J2	10-25-52	70
	5-13-58	69
	12- 4-59	65
	12-11-59	65
	1- 6-60	65
17M1	5- 9-60	69
	11-26-62	66
17M2	4-29-64	68
17M3	6- 9-60	70
	12-23-60	64
	6- 9-61	64
	12- 6-61	64
	11-26-62	70
	5-14-69	66

Table A III. Logs of water wells on or near Point Mugu and Port Hueneme, California. Data from Page, (1963) and California Department of Water Resources (1963).

	Thickness (feet)	Depth (feet)
IN/21-27F1. Broome Ranch (Alt. 13.7 ft. Drilled by Henry Hatherly in 1926. 18-in. casing, perforated 425-426, 457-460, 584-588, 611-616, 687-692, 703-710, 749-757, and 824-838 ft.)		
Clay--	134	134
Clay with a little gravel----------------------	1	135
Blue clay and hardpan------------------------	250	385
Red Clay------------------------------------	36	421
Blue clay-----------------------------------	4	425
Gravel, water-bearing------------------------	1	426
Red sandy clay------------------------------	24	450
Blue clay-----------------------------------	5	455
Gravel--------------------------------------	2	457
Sand, blue clay-----------------------------	13	470
Blue sand-----------------------------------	13	483
Blue clay-----------------------------------	7	490
Red clay------------------------------------	30	520
Red clay and gravel, water--------------------	10	530
Blue clay with a little sand-------------------	50	580
Cemented gravel-----------------------------	4	584
Blue clay-----------------------------------	24	608
Cemented formation--------------------------	3	611
Blue sand-----------------------------------	66	677
Blue clay-----------------------------------	3	680
Sand, gravel, and shells----------------------	3	683
Cemented formation with shells-----------------	4	687
Blue sand-----------------------------------	14	701
Layers of cement formation and shells----------	4	705
Blue clay and silt----------------------------	38	743
Gravel, not much water-----------------------	6	749
Sand--	63	812
Gravel--------------------------------------	12	824
Solid rock-----------------------------------	16	840
IN/21-31L1 (supply well 3). NAMTC (Alt 8,89 ft. Drilled by Van Noy in 1949. 26-in. casing to 310 ft. 16-in. casing to 360 ft. 12-in. casing to 1,000 ft: originally perforated 350-420, 476-530, 620-700, and 810-972 ft. Cement plug reportedly set in well at 750 ft. after 1950. Log by T.L. Bailey, consulting geologist).		
Sand, mostly fine------------------------------	95	95
Sand, coarse, and gravel and streaks of blue clay--	39	134

IN/21-31L1 --continued

	Thickness (feet)	Depth (feet)
Sand, light-gray, fine, and blue clay----------	78	212
Gravel, light-gray, clean----------------------	59	271
Clay, blue, and thin silty sand and gravel streaks--------------------------------	79	350
Sand, gravelly and pebbly----------------------	70	420
Clay, blue-gray--------------------------------	20	440
Sand, fine, silty------------------------------	12	452
Clay, dark-gray--------------------------------	15	467
Gravel and coarse sand-------------------------	71	538
Sand, medium to fine, silty--------------------	64	602
Sand, dark-gray, silt and silty----------------	18	620
Sand, coarse, and gravel-----------------------	70	790
Clay, blue, fine to medium, and sandy silt-----	42	732
Sand, medium to fine, and gravelly streaks-----	50	782
Silt, blue and fine sand-----------------------	28	810
Sand and gravel, medium to coarse--------------	80	800
Sand, medium to coarse, and fine silty sand streak--	68	958
Sand, medium to coarse (fair water)------------	42	1,000
Sand, medium to coarse (brackish water)--------	50	1,050
Silt, blue-gray, sandy and fine silty sand-----	60	1,110
Clay, blue-gray, shaly-------------------------	50	1,160
Sand, dark-gray, medium to fine, carbonaceous--	40	1,200
Clay, dark-gray, carbonaceous, shale, and sandy shale-------------------------------	18	1,218
Shale, gray, clayey, and shaly clay------------	128	1,346
Shale, light-gray, silty, thinner beds of friable sandstone--------------------------	124	1,470
Shale, soft, carbonaceous----------------------	12	1,482
Sandstone, dark, friable, interbedded with brownish-black soft laminated clay-shale----	61	1,543
Sandstone, dark-gray, hard---------------------	30	1,573
Basalt, dark-green, altered--------------------	10	1,583

IN/21-32A1 (supply well 5). NAMTC
(Alt about 10 ft. Drilled by Midway Drilling Co. in 1958. 16-in. casing perforated from 645-745 ft. Log by Geol. Survey)

Silts, greenish-brown, fine sand lenses--------	75	75
Sand, coarse, pebble-size, well-rounded, some marine shells-------------------------------	20	95
Clay, silty, fine sand-------------------------	20	115
Sand, coarse, pebble-size, well-rounded, some fine sand, marine shells--------------------	21	136
Clay, silty, bluish-gray, some coarse sand-----	14	150
Sand, coarse, pebble-size, subrounded to rounded, some marine shells-----------------	20	170
Clay, bluish-gray, fine sand-------------------	9	179
Sand, fine to coarse, subrounded to rounded----	10	189
Clay, bluish-gray, fine sand-------------------	10	199

IN/21-32A1--continued	Thickness (feet)	Depth (feet)
Sand, fine, silty, well-rounded	9	208
Clay, bluish-gray, fine sand	7	215
Sand, fine to coarse, well-rounded, silts	14	229
Clay, fine sand	10	239
Sand, fine, to coarse, some silt	12	251
Clay, brown, silt and fine sand	18	269
Silt to coarse sand, little clay, shell fragments	113	382
Clay, silt, fine sand	13	395
Sand, fine to medium, some silt, clay, and shell fragments	65	460
Clay, silt, some fine sand	16	476
Sand, fine to medium, blue-gray, well-rounded, some silts and clays	134	610
Clay, blue-gray, fine sand and silt	26	636
Sand, fine to medium, well-rounded, blue-gray, some silts and clays	116	752
Sand, fine to medium, well-rounded, blue-gray, some silts and clays	51	803

IN/21-32G1 (supply well 1). NAMTC
(Alt 10.00 ft. Drilled in 1943. 12-in. casing perforated 121-137, 311-325, and 417-432 ft. Log from Navy, presumably by driller)

Soil	3	3
Clay, yellow	19	22
Clay, blue	12	34
Sand, fine	18	52
Clay, sandy	14	66
Clay, blue	12	78
Sand, fine	20	98
Clay, blue	24	122
Sand	14	136
Sand and 1-inch gravel	16	152
Clay, yellow	4	156
Sand, fine	12	168
Clay, yellow	12	180
Sand, fine, and gravel	12	192
Clay, blue	13	205
Sand, blue, fine	35	240
Clay, blue	4	244
Sand, blue	12	256
Clay, blue	23	279
Sand, blue	3	282
Clay, blue, sandy	10	292
Sand, fine	6	298
Clay, blue	14	312
Gravel, 2-inch	12	324
Clay, blue	6	330
Sand, blue	36	366
Sand and gravel, cemented	12	378

IN/21-32G1--continued

	Thickness (feet)	Depth (feet)
Gravel	6	384
Sand, blue, coarse	14	398
Sand, blue, fine	8	406
Clay, blue	2	408
Sand, blue, fine	26	434

IN/21-32K1 (supply well 2). NAMTIC

(Alt. 9.46 ft. Drilled in 1943. 12-in. casing perforated 460-170, 544-550, and 575-593 ft. Log from Navy, presumably by driller.)

	Thickness (feet)	Depth (feet)
Soil	3	
Clay, yellow	17	20
Clay, blue	15	35
Sand, blue, fine	39	74
Clay, blue	20	94
Sand, blue, fine	4	98
Clay, blue	26	124
Clay, yellow	14	138
Sand, yellow, fine	12	150
Clay, blue	10	160
Sand, yellow	26	186
Clay, yellow	16	202
Sand, blue, fine	26	228
Clay, blue	62	290
Sand, blue, fine	6	296
Shale, blue	10	306
Sand, cemented	14	320
Sand, blue, fine	12	332
Sand, blue	28	360
Sand, blue, fine	30	300
Sand, blue	70	460
Sand and gravel	10	470
Sand, blue	38	508
Sand, blue, and some shells	12	520
Sand, blue, fine	24	544
Sand and gravel	6	550
Sand, blue	22	572
Sand and gravel	18	590
Clay, blue, sandy	32	622

IN/R22W-19A1

Depth in feet.

0- 5..........Soil
5- 40..........Sand
40- 60..........Clay
60-122..........Sand
122-190..........Blue clay
190-200..........Brown clay
200-232..........Sand and gravel
232-272..........Blue clay
272-370..........Cemented sand and gravel
370-504..........Blue clay
504-520..........Gravel
520-566..........Cemented sand
566-590..........Tight gravel
590-610..........Clay and gravel
610-638..........Sand and gravel
638-668..........Fine sand
668-692..........Hard blue clay
692-608..........Sand and gravel
708-726..........Blue clay
726-747..........Sand and gravel
747-766..........Blue clay

IN/R22W-20B1

0- 7..........Soil
7- 42..........Soil
42- 90..........Clay
90-116..........Sand
116-143..........Clay
143-176..........Gravel and sand
176-183..........Clay
183-223..........Gravel
223-268..........Clay
268-305..........Gravel
305-317..........Sea mud
317-324..........Clay

IN/R22W-20H1

0- 6..........Silty clay
6- 17..........Sand and gravel
17- 30..........Silty clay
30- 55..........Silty clay
55- 78..........Silty clay
78- 92..........Sand
92-106..........Sand
106-117..........Sandy silt
117-138..........Silty clay
138-149..........Sand
149-190..........Sand and gravel

IN/R22W-20H1 continued

Depth in feet.

190-197..........Sand and gravel
197-211..........Sand
211-230..........Silty clay

IN/R22W-20E2

0- 4.........Beach sand
4- 24.........Blue clay
24- 51.........Sand
51- 70.........Blue clay
70- 82.........Fine sand
82- 90.........Blue clay
90- 127.........Sand and gravel
127- 145.........Blue clay
145- 162.........Sand and gravel
162- 184.........Blue clay
184- 206.........Brown clay
206- 236.........Sand and gravel
236- 285.........Brown clay
285- 315.........Sand and gravel
315- 402.........Sea bottom mud
402- 514.........Blue clay
514- 540.........Sand and gravel
540- 602.........Fine sand
602- 638.........Blue clay
638- 660.........Fine blue sand
660- 680.........Blue clay
680- 692.........Blue sand
692- 698.........Sand and gravel
698- 710.........Blue clay
710- 740.........Fine sand
740- 770.........Blue clay
770- 820.........Fine blue sand
820- 924.........Sea bottom silt
924- 940.........Coarse sand
940- 974.........Sand and gravel
974-1014.........Blue sand

IN/R22W-21C1

0-166..........Soil, sand and gravel
166-200..........Gravel
200-210..........Clay
210-224..........Gravel
224-244..........Clay
244-266..........Gravel and sand
266-281..........Clay

IN/R22W-16D4

Depth in feet.

0-150.........Sand
150-315.........Sand and boulders
315-360.........Sand and rock
360-420.........Rock and clay
420-500.........Sand and rock
500-608.........Blue clay
608-650.........Shale and sand
650-680.........Clay and sand
680-720.........Coarse sand
720-740.........Clay and sand
740-1106........Sand and boulders

IN/R22W-17B1

0- 80.......Sand
80- 90.......Sandy shale
90- 130.......Sand
130- 150.......Sandy shale
150- 180.......Coarse sand
180- 220.......Sand
220- 255.......Sand
255- 270.......Sand and gravel
270- 310.......Sand and gravel
310- 370.......Coarse sand and gravel
370- 390.......Sand and gravel
390- 400.......Sandy shale
400- 440.......Sand
400- 450.......Fine sand
450- 500.......Fine sand and gravel
500- 510.......Shale, sand and gravel
510- 520.......Sand
520- 540.......Sand and gravel
540- 580.......Fine sand
580- 610.......Sand
610- 620.......Fine sand and gravel
620- 630.......Sand and gravel
630- 640.......Sand
640- 660.......Sand and gravel
660- 670.......Fine sand and gravel
670- 680.......Shale and gravel
680-1014.......Sand and gravel
1014-1070.......Clay
1070-1100.......Sand
1100-1280.......Shale

IN/R22W-17C2

Depth in feet.

0- 4..........Top soil
4- 21..........Fine sand and gravel
21- 39..........Blue clay
30- 53..........Gravel
53- 87..........Blue clay
87-114..........Sand
114-133..........Gravel
133-152..........Blue clay
152-165..........Gravel
165-214..........Brown clay
214-248..........Gravel

IN/R22W-17M3

0- 2..........Silt
2- 10..........Sand
10- 24..........Sand
24- 32..........Clay
32- 44..........Sand
44- 58..........Clay
58- 78..........Clay
78- 96..........Gravel
96-100..........Sand and clay
100-106..........Sand and gravel
106-110..........Sand
110-125..........Clay
125-145..........Clay
145-172..........Clay
172-194..........Clay
194-200..........Sand
200-206..........Sand and gravel
206-217..........Sand and gravel
217-230..........Sand and gravel
230-234..........Sand and gravel
234-236..........Clay
236-238..........Clay
238-240..........Sand
240-242..........Clay
242-282..........Clay
282-284..........Sand
284-298..........Clay
298-300..........Sand and gravel
300-322..........Sand

IN/R22W-20H6

Depth in feet.

0- 16	Med.-coarse sand
16- 25	Fine-med. sand
25- 29	Med.-cse. sand and gravel
29- 36	Silty clay
36- 41	Sand
41- 47	Silty clay
47- 80	Silty clay
80- 92	Sand and silty clay
92-108	Med.-cse. sand
108-116	Silty clay
116-138	Silty clay
138-140	Sand and silty clay
140-178	Sand and gravel
178-180	Gravel
180-198	Sand and gravel
198-204	Gravel
204-222	Sand and gravel
222-231	Silty clay
231-232	Silty clay
232-237	Sand
237-244	Sand and gravel
244-271	Silty clay
271-272	Silty sand
272-311	Sand and gravel
311-317	Sand and silty clay
317-328	Sand and silty clay
328-350	Silty clay

Table A IV. Chemical analyses of waters from selected wells on or near Point Mugu and Port Hueneme, California. Data from Page, 1963. (Constituents (in parts per million). The sum of determined con stituents is the sum of the constituents analyzed except for bicarbonate which is divided by 2.03 (Collins, 1928, p. 253). All values have been rounded where necessary to conform to the standards of the Geological Survey. Analyzing laboratory. DA, U.S. Dept. of Agriculture; DWR, California Dept. Water Resources; F, Fruit Growers Association; GS, Geol. Survey; N, U.S. Navy; U. United Water Conservation District.)

Well	Analyzing laboratory and number	Depth (ft)	Date collected	Temp (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Sum of determined constituents	% Sodium	Ph
IN/21-27F1	F-2128	840	Nov. 25, 1932	---	---	---	72	58	[1] 295	----	431	----	292	283	---	-----	----	1,430	1,210	60	----
	F9369-5	---	July 27, 1949	---	---	---	72	20	[1] 278	----	404	41	74	302	---	-----	----	------	995	67	----
28G2	F	370	Feb. 9, 1927	---	---	---	138	59	[1] 93	----	401	----	163	206	---	-----	----	1,060	857	28	----
	F-7890	---	May 14, 1947	---	---	---	135	43	[1] 115	----	305	----	351	106	---	-----	0.33	1,060	900	33	----
29D1	F-7865	570	Apr. 22, 1947	---	---	---	112	30	94	12	267	0	317	49	---	-----	.39	831	746	33	----
29D2	4031A	602	Oct. 24, 1957	---	---	---	120	37	[1] 97	----	284	----	358	42	---	-----	.66	938	795	32	----
29R1	F-182A	205	Dec. 6, 1960	---	---	---	160	67	333	17	307	----	535	430	---	-----	----	1,850	1,690	51	----
	F-3432A	---	Oct. 16, 1956	---	---	---	115	39	[1] 99	----	380	----	328	54	---	-----	.47	935	783	32	----
31J1	GS-25033	600	Jan. 7, 1958	75	43	0	86	39	96	5.7	266	0	250	68	0.3	1.0	.40	747	720	35	7.4
31L1	F-8096	750	Feb. 15, 1949	---	---	---	74	36	136	4	332	----	198	110	---	-----	----	890	722	47	----
	GS-25032	---	Jan. 7, 1958	---	44	---	84	37	96	5.7	290	0	240	52	.3	1.3	.49	736	704	36	7.2
32A1	GS-28199	750	Oct. 23, 1958	---	46	---	98	42	182	6.6	316	0	261	192	---	.6	.6	------	985	48	7.5
32G1	F-8316	434	Feb. 9, 1948	---	---	---	118	37	[1] 92	----	231	2	333	47	---	-----	.37	908	767	31	----
	GS-25030	---	Jan. 7, 1958	69	39	0	162	42	99	4.9	274	0	355	140	.3	.6	.63	1,010	973	27	7.3
32K1	F-8317	622	Feb. 9, 1948	---	---	---	90	43	117	----	254	----	333	68	---	-----	.30	905	776	39	----
	GS-25031	---	Jan. 7, 1958	---	39	0	108	38	96	5.6	276	0	293	75	.3	2.2	.57	819	794	33	7.1
IN/22-26A1	DA-4031	236	Apr. 15, 1931	---	---	---	122	38	[1] 84	----	353	----	362	41	---	-----	.54	------	773	28	----
	F-9196	---	May 5, 1949	---	---	---	125	34	[1] 90	----	255	----	361	44	---	-----	----	909	789	30	----
	F-3431A	---	Oct. 16, 1956	---	---	---	128	32	100	----	263	----	365	42	---	-----	.49	930	797	32	----
28A1	F-9193	---	May 5, 1949	---	---	---	147	44	[1] 121	----	255	----	490	56	---	-----	.64	1,110	985	32	----
	F-4033A	---	Oct. 24, 1957	---	---	---	119	39	[1] 94	----	280	----	358	40	---	-----	.66	930	782	31	----
28B1	---------	230	May 8, 1958	---	---	---	370	137	[1] 182	----	241	----	463	850	---	-----	----	------	2,190	21	----
29A2	DWR-1900	---	Mar. 3, 1933	---	---	---	126	41	[1] 98	----	245	----	404	52	---	-----	.62	966	843	31	----
	U-7808	225	Mar. 31, 1947	---	---	---	121	41	89	7	253	0	395	42	---	3	.52	954	827	28	----
36K1	U-1960	186	Apr. 3, 1933	---	---	---	119	36	95	----	275	0	353	40	---	-----	.60	918	779	32	----
	F-9195	---	May 5, 1949	---	---	---	119	32	[1] 94	----	265	----	335	45	---	1	----	891	757	32	----
	F-4048A	---	Oct. 28, 1957	---	---	---	154	39	[1] 112	----	265	----	331	162	---	-----	.60	1,060	930	31	----
IS/21-4E1*	N	350	July 7, 1949	---	---	---	125	51	[1] 229	----	279	49	385	307	---	Trace	----	1,420	1,280	49	----
	GS-24811 [2]	---	Jan. 10, 1958	---	8.2	.13	1,720	75	4,380	65	105	0	1,110	11,600	.2	9.6	1.0	20,300	19,000	56	6.4
6F1**	GS-24808	350	Jan. 10, 1958	---	---	---	------	---	------	----	254	4	-----	90	---	-----	----	------	------	--	6.3

*IS/21-4E1 (below packer)

**6F1 (above packer)

1 Potassium included

2 CO_2, 66ppm

APPENDIX II-B.

TWENTYNINE PALMS SITE

Table BI. Locations of wells on or near the Marine Corps Training Center, Twentynine Palms, California.

State Well Number	Date of Observation	Depth (ft.)	Temp. (F)	L	WA	WL
1N/7E-14N1*	6-3-58	450	--	X		X
1N/8E-1B1*	1959-60	--	--			X
1N/8E-12G1*	1960	420	--			X
1N/9E-4N1*	1959-60	500	--			X
1N/9E-4N3*	4-4-58	500	64		X	X
1N/9E-5G1*	4-8-58	500	--		X	X
1N/9E-5H1*	1959-60	93.8	--			X
1N/9E-5Q2*	1959-60	184	--			X
1N/9E-7H1*	1959-60	110	--			X
1N/9E-9M2*	1959-60	61.5	--			X
1N/9E-16D1*	1959-60	96	--			X
1N/9E-16H3*	1959-60	153.9	--			X
1N/9E-17E1*	1959-60	133	--			X
2N/6E-12R1	1-28-53	194	--			
	11-11-60	15	--			
2N/7E-2C1	11-9-60	400	93	X	X	X
2N/7E-3A1	11-9-60	560	84	X	X	X
2N/7E-3B1	11-9-60	700	82	X	X	X
2N/7E-4H1	11-9-60	500	80	X	X	X
2N/7E-14K1	11-9-60	644	96	X	X	X
2N/8E-11B1	11-10-60	1	71		X	X
2N/8E-13A1	4-26-52	154.3	--			
	11-10-60	152.7	--			
2N/8E-24H1	11-9-60	320	85	X	X	X

2N/8E-26J1*	1959-60	185	--			X
2N/8E-32K1*	--	414	--			
2N/8E-32R1*	--	414	--			
2N/9E-19D1	4-26-52	146	--			
	11-9-60	120.3	--			
2N/9E-30P2*	1959-60	55.8	--			X
3N/6E-3N1	5-8-52	133.9	--			
	2-24-53	132	--			
	11-11-60	131.8	--			
3N/6E-4L1	11-11-60	137	--		X	
3N/6E-4L2	5-8-52	76	--			
	11-11-60	64.4	--			
3N/6E-4P1	5-8-52	132	--		X	
	11-11-60	125.3	--			
3N/6E-35N1	1-27-53	--	--			
	11-11-60	--	--			
3N/7E-13N1	11-9-60	188.5	83	X	X	X
3N/7E-18D1	11-11-60	384.5	74	X	X	X
3N/7E-31E1	11-11-60	430	78	X	X	X
3N/7E-35L1	11-9-60	0	--			X
3N/7E-35P1	11-9-60	16	--		X	X
3N/7E-35P2	--	605	--	X		
3N/8E-17L1	11-10-60	512	83	X	X	X
3N/8E-29C1	11-9-60	800	85	X	X	X
3N/8E-29L1	11-9-60	600	79	X	X	X
3N/8E-33B1	11-9-60	526	72	X	X	X

3N/8E-34D1	4-26-52	400	74	X	X
	11-9-60	400	--		
4N/6E-18F1	11-1-53	39.1	--	X	
	11-11-60	2	--		
4N/6E-27C1	5-8-52	63.1	--		
	1-29-53	63.1	--		X
	11-11-60	57.5	--		
4N/6E-27C2	6-23-54	73.5	--		
	11-11-60	5	--		
4N/6E-27D1	4-30-52	80.2	--		
	1-29-53	80.2	--		X
	11-11-60	80	--		
4N/6E-27F1	5-8-52	182.3	--		
	1-29-53	182.3	--		X
	11-11-60	182.3	--		
4N/6E-27M1	1-29-53	--	--		X
	11-11-60	150	--		
4N/6E-28R1	5-8-52	150	--		
	1-29-53	150	--		
	11-11-60	133.5	--		
4N/6E-34E1	11-11-60	116.7	--		
5N/6E-3N1	11-11-60	40	--		

*Outside the Marine Reserve Boundaries

L: Log included.
WA: Water analysis included.
WL: Water levels included.

Table B II. Water-level measurements of wells on or near the Marine Corps Training Center, Twentynine Palms, California

IN/8-1B1. Royer. Altitude 1,903 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 7, 1959	125.06	Nov. 7, 1959	125.29	Mar. 2, 1960	125.19
Aug. 12	125.20	Dec. 11	125.34	Apr. 4	125.23
Sept. 9	125.24	Jan. 4, 1960	125.25	May 3	125.24
Oct. 6	125.25	Feb. 1	125.22	June 6	123.70

IN/8-12G1. W. Hockett. Depth 420 ft. Altitude 1,972.7 ft.

Date	Water Level	Date	Water Level	Date	Water Level
Sept. 9, 1959	197.10	Jan. 4, 1960	197.2	Apr. 4, 1960	197.06
Nov. 7	197.13	Feb. 1	197.30	May 3	197.02
Dec. 11	197.14	Mar. 2	197.11		

IN/9-4N1 (SW 1). U.S. Navy. Depth 500 ft. Altitude 1,786.8 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 7, 1959	13.12	Nov. 7, 1959	13.15	Mar. 2, 1960	13.07
Aug. 12	13.80	Dec. 10	13.15	Apr. 3	13.05
Sept. 9	13.79	Jan. 4, 1960	13.10	May 3	b13.66
Oct. 6	13.25	Feb. 1	13.31	June 6	b13.70

IN/9-4N3. U.S. Navy. Depth about 500 ft. Altitude about 1,787 ft.

Date	Water Level	Date	Water Level	Date	Water Level
Nov. 13, 1946	11.62	Nov. 27, 1953	16.19	Jan. 18, 1957	12.98
Feb. 13, 1952	11.84	Apr. 22, 1954	23.50	Apr. 26	12.79
Nov. 25, 1952	13.10	Dec. 20, 1955	12.57	Dec. 18	12.91
May 27, 1953	15.10	Apr. 26, 1956	12.58	Apr. 4, 1958	12.83

IN/9-5G1 (SW 2). U.S. Navy. Depth 500 ft. Altitude 1,779.2 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 7, 1959	5.32	Dec. 9, 1959	6.00	Mar. 2, 1960	6.24
Oct. 6	5.40	Jan. 4, 1960	6.21	Apr. 3	6.14
Nov. 7	5.30	Feb. 1	b7.12	May 3	a52.9

IN/9-502. W. Singleton. Depth 148 ft. Altitude 1,801 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 7, 1959	28.91	Nov. 7, 1959	29.07	Mar. 2, 1960	28.73
Aug. 12	29.02	Dec. 9	28.96	Apr. 3	28.70
Sept. 9	29.15	Jan. 4, 1960	28.86	May 3	28.76
Oct. 6	29.11	Feb. 1	28.81	Jun3 6	28.95

Date	Water Level	Date	Water Level	Date	Water Level
IN/9-5R1. M. Elliott. Depth 93.8 ft. Altitude 1,788.8 ft. Mar. 2, 1960, 19.54; Apr. 3, 19.46; May 3, 19.45.					
IN/9-7H1. Paul Carson. Depth 110 ft. Altitude 1,843.3 ft.					
July 7, 1959	69.53	Nov. 7, 1959	69.22	Mar. 2, 1960	69.48
Aug. 12	69.65	Dec. 11	69.55	Apr. 3	69.50
Sept. 9	a69.77	Jan. 4, 1960	69.56	May 3	69.59
Oct. 6	69.81	Feb. 1	69.55	June 6	69.67
IN/9-9M2. Head. Formerly Taylor. Depth 61.5 ft. Altitude 1,810.0 ft.					
July 7, 1959	38.11	Nov. 7, 1959	38.20	Mar. 2, 1960	37.99
Aug. 12	38.60	Dec. 9	38.15	Apr. 3	37.98
Sept. 9	38.44	Jan. 4, 1960	38.17	May 3	37.94
Oct. 16	38.35	Feb. 1	38.01	June 6	38.15
IN/9-16D1. United. Depth 96 ft. Altitude 1,812.9 ft.					
July 7, 1959	a44.65	Nov. 7, 1959	40.30	Mar. 2, 1960	b45.83
Aug. 12	40.25	Dec. 9	a48.95	Apr. 3	40.28
Sept. 9	a42.02	Jan. 4, 1960	b45.85	May 3	a55.3
Oct. 6	a46.90	Feb. 1	45.14	June 6	a53.57
IN/9-16H3. G. Michells. Depth 153.9 ft. Altitude 1,777 ft.					
July 7, 1959	12.08	Dec. 10, 1959	11.37	Mar. 2, 1960	10.94
Aug. 12	11.43	Jan. 5, 1960	11.16	Apr. 3	10.97
Sept. 9	12.31	Feb. 1	11.03	May 4	11.08
Oct. 6	11.17				
IN/9-17E1. Barry. Depth 133 ft. Altitude 1,882.7 ft.					
July 7, 1959	108.12	Nov. 7, 1959	108.26	Mar. 2, 1960	108.03
Aug. 12	108.20	Dec. 10	108.22	Apr. 4	108.18
Sept. 9	108.24	Jan. 4, 1960	108.18	May 3	108.23
Oct. 6	108.25	Feb. 1	108.19	June 6	108.50
2/7-2C1. Altitude 2,272.1 ft. Depth 400 ft.					
Apr. 21, 1952	a25.44	May 10, 1954	c26.73	June 12, 1955	c28.83
July 8	25.50	15	c26.54	30	c29.13
Sept. 10	25.61	20	c26.44	July 4	c28.95
Oct. 2	25.55	31	a26.33	18	c29.66
Jan. 29, 1953	25.29	June 16	26.24	29	c29.95
Feb. 3	b26.50	30	c26.72	Aug. 15	c29.45
20	25.80	July 10	c27.13	Sept. 1	c28.85
Mar. 27	25.55	18	c27.38	28	c28.44
May 2	25.46	Aug. 1	c27.75	Oct. 15	c30.20
30	25.42	11	c28.04	29	c31.20

Table B II cont.

June	25	25.41	Aug.	24	c28.26	Nov.	30	c31.80
July	15	c25.46	Sept.	1	c28.20	Dec.	2	c31.45
	31	c25.50		8	c28.17		31	c32.65
Aug.	5	c25.51		11	c28.40	Jan.	19, 1956	c33.40
	10	c25.60		15	c28.10		22	c32.85
	14	c25.74		24	c27.85	Feb.	4	c32.23
	24	c25.65	Oct.	1	c27.65		12	c32.80
	30	c25.79		9	c27.45		20	c32.10
Sept.	10	c25.88		15	c27.48	Mar.	1	c32.48
	20	c25.94		21	c27.77		16	c33.15
	30	c25.99	Nov.	1	c27.43	Apr.	9	c32.55
Oct.	10	c26.05		15	c27.24		20	c33.15
	20	a25.98		25	c27.14	May	1	c33.35
	30	c26.10		30	c27.31		16	c33.34
Nov.	10	c26.15	Dec.	8	c27.57	June	30	c34.59
	20	c26.21		13	c27.62	July	4	c34.60
	30	c26.04		19	c27.88		20	c35.23
Dec.	11	c26.35	Jan.	1, 1955	c27.89	Aug.	5	c35.32
	20	c26.12		11	c28.02		31	c36.70
	27	c26.01		16	c27.78	Sept.	9	c35.98
Jan.	3, 1954	c26.40		31	c27.63		28	c38.48
	22	c26.01	Feb.	14	c27.80	Oct.	5	c36.42
Feb.	4	c25.92		28	c27.80		20	c35.81
	19	c26.28	Mar.	15	c28.00	Nov.	7	c35.40
Mar.	3	c26.35		23	c27.86		25	c35.80
	10	c26.28		31	c28.00	Dec.	5	c35.97
	20	c26.27	Apr.	15	c28.25		21	c35.84
	31	c26.50		30	c28.41	Jan.	10, 1957	c34.78
Apr.	10	c26.54	May	15	c28.66		24	c34.68
	19	c26.58		31	c28.74	Feb.	8	c35.03
	20	c26.62						
Mar.	5, 1957	c35.69	Jan.	10, 1958	37.37	Feb.	6, 1959	38.74
Apr.	3	c35.66		17	c37.36	Mar.	12	38.73
May	7	c38.43	Feb.	9	c36.86	Apr.	7	38.94
June	6	c36.22		10	36.97	May	11	39.51
July	5	36.68		29	c37.17	June	10	39.81
	10	c36.56	Mar.	9	c36.86	July	7	39.98
Aug.	3	c37.15		11	36.80	Aug.	12	40.80
	6	37.12		21	c37.09	Sept.	9	41.11
	23	c37.65	Apr.	9	c36.77	Oct.	6	41.21
Sept.	3	c36.89		15	37.00	Nov.	7	41.15
	9	37.01	May	14	37.22	Dec.	9	41.09
	10	c36.94		26	c36.98	Jan.	5, 1960	40.63
Oct.	4	c37.65	June	13	c37.44	Feb.	2	41.15
	7	37.47		14	38.09	Mar.	2	41.32
	18	c37.78	July	15	37.97	Apr.	4	41.71
Nov.	6	c37.17	Aug.	12	38.40	May	4	41.94
	7	37.24	Sept.	11	38.74	June	7	42.63
	11	c37.28	Oct.	8	38.97	July	8	43.81

Dec. 6	c37.96	Nov. 6	39.05	Aug. 9	43.20
9	37.97	Dec. 4	38.54	Sept. 2	43.34
12	c38.02	Jan. 6, 1959	38.30	Oct. 4	43.27
Jan. 8, 1958	c37.24			Nov. 9	43.19

a. Measurement by W. O. Wagner.
b. Nearby well being pumped.
c. Selected from recorder charts.

2/7-3A1. Altitude 2,300.9 ft. Depth 560 ft.

Feb. 1, 1953	c84.26	Feb. 22, 1955	56.98	Aug. 6, 1957	e69.03
5	55.49	Mar. 16	d57.18	Sept. 9	67.50
13	55.02	Apr. 16	57.34	Oct. 7	e69.00
20	54.87	May 17	57.96	Nov. 7	67.16
Mar. 27	54.55	June 17	58.04	Dec. 9	e70.39
May 2	54.44	July 21	e59.50	Jan. 10, 1958	e68.46
30	54.39	Aug. 25	58.24	Feb. 10	66.92
June 25	54.41	Sept. 23	57.51	Mar. 11	66.47
Aug. 6	54.50	Oct. 17	d72.90	Apr. 15	e68.50
Sept. 9	55.65	Nov. 23	d78.52	June 14	e67.96
Dec. 23	55.09	Dec. 22	d77.06	July 14	67.66
Jan. 22, 1954	55.00	Jan. 24, 1956	62.20	Aug. 12	e70.19
Mar. 2	55.36	Mar. 1	62.29	Oct. 8	e69.66
30	56.73	Apr. 4	62.53	Jan. 6, 1959	68.69
31	55.59	June 5	e64.64	Feb. 6	e70.00
May 3	57.28	July 3	e65.83	Mar. 12	68.44
4	55.77	Sept. 6	e67.52	May 11	e70.94
June 25	55.72	Oct. 5	e68.20	June 10	e70.31
July 21	d72.13	Nov. 7	e67.37	July 7	69.87
22	56.87	Dec. 4	65.64	Sept. 9	e72.73
Aug. 23	d72.48	Jan. 10, 1957	64.15	Nov. 7	71.01
24	57.74	Feb. 8	64.63	Jan. 4, 1960	e72.14
Sept. 24	57.03	Mar. 6	65.37	Mar. 2	e72.48
Nov. 20, 1954	56.21	May 8	65.68	Apr. 4	e73.31
Dec. 21	57.29	June 6	e68.77	May 4	71.87

d. Well being pumped.
e. Pumped recently.

2/7-3B1. Altitude 2,355.3 ft. Depth 700 ft.

Jan. 10, 1953	104.68	Jan. 21, 1955	106.64	Aug. 6, 1957	e119.13
14	d155.75	Mar. 16	105.14	Sept. 9	e116.67
12	104.87	Apr. 15	106.81	Oct. 7	e116.58
Feb. 20	104.77	May 17	106.50	Nov. 7	113.49
Mar. 27	104.67	June 17	106.46	Dec. 9	111.73
May 2	104.68	July 21	107.34	Jan. 10, 1958	111.12
30	104.69	Aug. 25	107.83	Feb. 11	111.10
June 25	104.70	Sept. 23	108.60	Mar. 11	112.69

Date	Water Level	Date	Water Level	Date	Water Level
July 9	104.69	Oct. 18	107.69	Apr. 15	e116.12
Aug. 6	104.89	Nov. 23	107.50	May 14	111.22
Sept. 9	105.07	Dec. 22	107.68	June 14	113.47
Dec. 23	e106.49	Mar. 1, 1956	108.20	July 14	113.16
Mar. 2, 1954	105.72	Apr. 4	109.69	Dec. 4	b114.60
30	e107.60	June 5	109.58	Jan. 6, 1959	113.39
31	105.77	July 3	109.84	Feb. 6	114.14
May 3	e108.57	Aug. 4	110.51	Mar. 12	e116.06
4	105.78	Sept. 6	e111.43	Apr. 7	114.42
June 25	106.26	Oct. 5	e114.30	July 7	e117.28
July 22	d140.6	Nov. 7	110.21	Sept. 9	e119.44
23	107.00	Dec. 4	e118.01	Nov. 7	e119.05
Aug. 23	d138.52	Jan. 10, 1957	e119.25	Jan. 5, 1960	e123.93
24	e107.44	Feb. 8	111.19	Feb. 2	115.20
Sept. 24	d140.42	Mar. 5	e114.84	Mar. 2	114.96
Nov. 20	107.35	Apr. 4	b116.36	Apr. 4	e119.20
Dec. 21	d143.20	May 8	e118.19	May 4	e117.26
22	e107.58	July 5	e116.62	Nov. 9	117.76

b. Nearby well being pumped.
d. Pumping.
e. Pumped recently.

2/7-14K1. Altitude 2,532.1 ft. Depth 644 ft.

Oct. 2, 1952	334.1	Feb. 22, 1955	335.89	Oct. 7, 1957	336.71
Feb. 19, 1953	334.49	Aug. 25	336.20	May 14, 1958	336.81
Nat 30	334.58	Oct. 17	336.17	Oct. 8	336.98
Aug. 7	335.00	June 5, 1956	336.20	Apr. 7, 1959	336.89
Mar. 3, 1954	335.4	Nov. 7	336.59	Mar. 4, 1960	336.97
Aug. 23	335.63	Mar. 6, 1957	336.70	Nov. 9	337.11
Jan. 21, 1955	335.63				

2/8-11B1. Altitude about 1,870 ft. Depth 64.6 ft.

Apr. 26, 1952	35.52	Jan. 23, 1953	35.56	July 10, 1953	35.64
May 28	35.53	Feb. 20	35.53	Aug. 8	35.64
July 7	35.58	Mar. 27	35.53	Sept. 9	35.71
Aug. 6	35.64	Apr. 30	35.52	Nov. 22	35.69
Oct. 4	35.62	May 29	35.57	Dec. 23	35.68
				Well destroyed	

2/8-24H1. Altitude 1,856.2 ft. Depth 320 ft.

Mar. 6, 1952	180.16	Mar. 16, 1955	80.62	Nov. 7, 1957	81.03
May 28	80.19	Apr. 16	80.64	Dec. 9	80.96
July 7	80.22	May 19	80.64	Jan. 10, 1958	80.95
Aug. 6	80.23	June 17	80.61	Feb. 10	80.98

Date	Water Level	Date	Water Level	Date	Water Level
Oct. 2	80.33	July 21	80.68	Apr. 15	80.94
3	80.28	Aug. 24	80.66	May 14	80.97
4	80.24	Sept. 23	80.67	June 14	80.98
23	80.25	Oct. 17	80.66	July 14	81.01
31	80.24	Nov. 23	80.77	Aug. 12	81.02
Jan. 23, 1953	80.38	Dec. 21	80.73	Sept. 11	80.60
Feb. 18	80.38	Jan. 24, 1956	80.69	Oct. 8	81.07
Mar. 27	80.45	Mar. 1	80.77	Nov. 6	81.06
Apr. 30	80.46	Apr. 4	80.63	Dec. 4	80.98
May 29	80.47	May 1	80.74	Jan. 6, 1959	81.01
July 10	80.45	June 5	80.81	Mar. 12	81.03
Aug. 8	80.50	July 2	80.85	Apr. 7	d86.67
Sept. 11	80.55	Aug. 3	80.86	May 11	81.06
Nov. 22	80.56	Sept. 5	80.84	June 10	d85.39
Dec. 23	80.57	Oct. 5	80.86	Sept. 9	81.24
Jan. 19, 1954	80.48	Nov. 6	80.85	Dec. 9	e84.83
Mar. 31	80.55	Dec. 4	80.85	Jan. 5, 1960	81.23
May 5	80.53	Jan. 10, 1957	80.90	Feb. 2	81.19
June 24	80.63	Feb. 7	80.91	Mar. 2	81.14
July 23, 1954	80.59	Mar. 5	80.91	Apr. 4	81.19
Aug. 24	80.63	Apr. 3	80.85	May 4	81.14
Sept. 24	80.61	May 7	80.85	June 7	81.85
Oct. 21	80.62	June 6	80.86	July 8	80.27
Nov. 20	80.63	July 5	80.88	Aug. 9	81.33
Dec. 22	80.61	Aug. 6	80.93	Sept. 2	81.39
Jan. 21, 1955	80.64	Sept. 9	80.91	Oct. 4	81.63
Feb. 22	80.59	Oct. 7	80.96	Nov. 9	81.36

3/7-13N1. Altitude 2,020.2 ft. Depth 501 ft.

Oct. 28, 1952	189.5	Dec. 2, 1952	189.40	June 25, 1954	189.43
30	189.39	6	189.36	Oct. 21	189.44
Nov. 3	189.42	May 30, 1953	189.37	Jan. 21, 1955	189.43
8	189.40	Aug. 6	189.36	June 17	189.45
13	189.36	Dec. 23	189.45	Oct. 17	189.39
				Well destroyed	

3/7-18D1. Altitude 2,403.7 ft. Depth 449 ft.

July 8, 1952	146.75	Oct. 21, 1954	146.81	Oct. 7, 1957	146.83
Nov. 10	146.80	June 17, 1955	146.83	May 14, 1958	146.81
Feb. 22, 1953	146.66	Oct. 18	146.77	Oct. 8	146.83
Aug. 7	146.72	June 5, 1956	146.83	May 4, 1960	146.97
Nov 21	146.76	Nov. 7	146.82	Nov. 11	146.94
June 23, 1954	146.77	Mar. 6, 1957	146.82		

3/7-31E1. Altitude 2,514.3 ft. Depth 430 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 8, 1952	249.96	June 17, 1955	249.76	Oct. 7, 1957	249.83
Jan. 26, 1953	249.90	Oct. 18	249.79	May 14, 1958	249.87
May 30	249.55	June 5, 1956	249.79	Oct. 8	249.86
Aug. 7	249.72	Nov. 7	249.84	Mar. 4, 1960	249.89
Mar. 5, 1954	249.85	Mar. 6, 1957	249.96	Nov. 11	249.83
Aug. 23	249.73				

3/7-35L1. Altitude 2,259.6 ft. Depth 36 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 8, 1952	13.51	Apr. 30, 1953	12.60	Aug. 6, 1953	13.03
Jan. 23, 1953	12.70	May 30	12.57	Sept. 11	13.28
Feb. 20	12.90	June 25	12.64	Well destroyed	
Mar. 27	12.73	July 9	12.91		

3/8-17L1. Altitude 1,850.4 ft. Depth 512 ft.

Date	Water Level	Date	Water Level	Date	Water Level
July 9, 1952	46.87	Apr. 15, 1955	47.12	Feb. 8, 1957	47.25
Oct. 30	46.85	May 17	47.19	Mar. 5	47.21
31	46.84	June 17	47.21	Apr. 3	47.21
Nov. 7	46.86	Aug. 25	47.24	May 7	47.18
13	46.85	Sept. 23	47.27	June 6	47.17
Dec. 2	46.88	Oct. 17	47.25	July 5	47.28
8	46.93	Nov. 23	47.26	Aug. 6	47.29
9	46.96	Dec. 22	47.23	Sept. 9	47.31
12	46.97	Jan. 24, 1956	47.23	Oct. 7	47.36
Jan. 17, 1953	46.87	Mar. 1	47.31	Nov. 7	47.41
May 29	46.86	Apr. 4	47.26	Dec. 9	47.39
Aug. 6	46.91	May 2	47.26	Jan. 10, 1958	47.40
Dec. 23	46.98	June 5	47.28	Feb. 10	47.44
Jan. 22, 1954	47.05	July 3	47.28	May 14	47.50
Oct. 21	47.08	Aug. 3	47.30	June 14	47.54
Nov. 20	47.10	Oct. 5	47.31	July 14	47.60
Dec. 21	47.09	Nov. 7	47.26	Nov. 6	47.72
Jan. 21, 1955	47.14	Dec. 4	47.25	Mar. 4, 1960	47.81
Feb. 22	47.10	Jan. 9, 1957	47.29	Nov. 10	47.93
Mar. 16	47.13				

3/8-29L1. Altitude 1,905.7 ft. Depth 600 ft.

Date	Water Level	Date	Water Level	Date	Water Level
Dec. 13, 1952	d129.39	May 17, 1955	d115.03	Nov. 7, 1957	102.94
14	102.27	June 17	102.68	Dec. 9	e103.03
15	102.20	July 21	102.51	Jan. 10, 1958	102.83
Feb. 20, 1953	102.07	Sept. 23	102.75	Feb. 10	102.87
Mar. 27	102.04	Oct. 17	d113.18	Mar. 11	102.76
Apr. 30	102.03	Nov. 23	102.68	Apr. 15	e103.40
May 30	102.02	Dec. 22	102.58	June 14	e103.28
June 25	102.04	Jan. 24, 1956	102.55	Aug. 12	e104.58

Date	Water Level	Date	Water Level	Date	Water Level
July 10	102.03	Apr. 4	102.53	Oct. 8	103.47
Aug. 8	102.04	May 2	102.44	Nov. 6	103.36
Nov. 22	e102.27	June 5	102.45	Dec. 4	103.30
Dec. 23	e102.28	July 3	102.47	Jan. 6, 1959	103.38
Mar. 2, 1954	e102.29	Aug. 3	102.42	Apr. 7	103.42
30	102.25	Sept. 6	102.43	May 11	e106.53
31	102.26	Oct. 5	102.43	June 10	103.41
May 3	102.17	Nov. 6	102.66	Aug. 12, 1959	103.40
5	d112.20	Dec. 4	102.52	Sept. 9	103.42
June 25	102.37	Jan. 10, 1957	102.47	Oct. 6	103.29
July 23	102.26	Feb. 7	102.43	Nov. 7	103.21
Aug. 23	102.23	Mar. 5	102.39	Dec. 9	103.18
Oct. 21	d113.82	Apr. 3	102.37	Jan. 5, 1960	103.15
Nov. 20	102.50	May 7	102.37	Feb. 2	103.14
Dec. 22	102.37	June 6	102.46	Mar. 2	103.08
Feb. 22, 1955	e102.43	July 5	102.76	Apr. 4	103.07
Mar. 16	102.42	Aug. 6	102.64	May 4	103.04
Apr. 16	102.41	Sept. 9	e103.01	July 8	103.24
May 17	102.53	Oct. 7	e102.95	Nov. 9	103.30

Table B III. Logs of wells on or near the Marine Corps Training Center, Twentynine Palms, California.

(Materials logged by the U.S.G.S., except as indicated.)

IN/7-14N1. U.S. Navy, formerly Twentynine Palms Air Academy. Altitude about 2,359 ft. Drilled by Mogle Bros. in 1943. 12-inch casing, perforated 386-425 ft.

	Thickness (feet)	Depth (feet)
Topsoil	16	16
Clay, sticky	66	82
Clay, black	10	92
Clay, sticky	294	386
Sand; water	39	425
Clay, sandy	25	450

2/7-2C1. Altitude 2,272.1 ft. Drilled by Mogle Bros. in 1952. 10-inch casing, perforated 149-152, 189-192, 239-259, 261-268, 271-305, and 256-377 ft. Cement plug at 400 ft.

Sand, fine to very coarse, light-orange, soft, windblown	13	13
Gravel, fine to coarse, light-buff, to light-orange, arkosic, soft	6	19
Clay, slightly sandy, calcareous, flocculent, light green-gray, hard	4	23
Gravel, fine, and sand, fine to very coarse, arkosic, calcareous, soft, with small basalt pebbles, water-bearing	1	24
Clay, slightly sandy to silty, calcareous, micaceous, light green-gray, hard	4	28
Gravel, fine, sandy, arkosic, soft; heaves up in well	5	33
Clay, slightly sandy, silty, micaceous, calcareous, sticky, light green-gray, hard	3	36
Sand, fine to very coarse, slightly silty and clayey, micaceous, light buff, packed, very hard, except from 42 to 46 feet which is soft and water-bearing	12	48
Clay, sandy, silty, calcareous, light brown, hard to soft	11	59
Silt, sandy, clayey, calcareous, micaceous, light green-gray; compact and fairly hard	8	67
Sand, coarse to very coarse, some silt, occasional pebbles; arkosic, light buff, compact and medium hard	4	71
Sand, very fine to medium, silty, clayey, buff, hard	7	78
Sand, fine to very coarse, silty, clayey, micaceous, arkosic, slightly iron-stained, soft, water-bearing	10	88
Gravel, fine; and sand, medium to very coarse, arkosic, micaceous, soft; water-bearing	5	93

	Thickness (feet)	Depth (feet)
2/7-2C1. continued.		
Gravel, fine to medium; sand, coarse to very coarse; clayey, brown-gray, angular, soft; water-bearing----	3	96
Sand, coarse to very coarse; and gravel, fine; arkosic, light buff, soft, water-bearing------------	20	116
Clay, sandy, calcareous, micacous, light yellow to brown, hard--	7	123
Sand, coarse to very coarse, gravelly; sand, fine, silty; and clay; in layers, buff to green to brown, moderately soft, with some sandstone concretions, water-bearing--	4	127
Sand, very fine to coarse, clayey, light yellow to buff, hard---	6	133
Sand, coarse to very coarse, some gravel, silty, clayey, light orange, soft----------------------------------	14	147
Sand, medium to very coarse, clayey, silty, light brown, hard---	2	149
Gravel, fine to coarse; and sand, coarse to very coarse; slightly silty, light buff, soft, water-bearing--	3	152
Sand, coarse to very coarse; and little gravel, in very thin laminae, silty, arkosic, light buff, soft, water-bearing----------------------------------	37	189
Sand, medium to very coarse, slightly silty and clayey, white to buff; contains thin cemented sand layers, very thin gravel layer at top, and a few calcareous sandstone concretions, in part water-bearing. Sand, clayey to slightly silty, strong sulfurous smell, temperature over 110°F, 225 to 227 feet; possibly a minor fault zone--------------	50	239
Sand, coarse to very coarse, slightly silty and clayey, with very small amount of gravel and a few pebbles; arkosic, micaceous, light to dark buff, soft, water-bearing--------------------------	10	249
Gravel, medium to coarse; and sand, coarse to very coarse; silty, clayey; micaceous, arkosic, white to buff, soft water-bearing------------------------	7	256
Gravel, coarse to fine, sandy, cobbley, angular to well rounded gray-buff, soft, water-bearing---------	3	259
Sand, fine to very coarse, cemented, hard----------------	2	261
Gravel, fine to coarse, sandy, cobbley, arkosic, soft, water-bearing--	7	268
Silt, sandy to clayey, light brown to green-gray, micaceous, hard------------------------------------	2	270
Gravel, cemented, nonwater-bearing----------------------	1	271

	Thickness (feet)	Depth (feet)
2/7-2C1. continued.		
Gravel, fine to coarse; sand, coarse to very coarse, layered; slightly iron-stained in upper few feet, but grading into a gray-buff to buff below, in part slightly silty, with a few calcareous sandstone concretions, soft, water-bearing throughout---	31	302
Gravel, medium to coarse, only slightly sandy, arkosic, light gray to buff, soft, clean, quite well sorted, soft, water-bearing----------------------------------	1	303
Sand, coarse to very coarse, silty, slightly clayey, gravelly, poorly assorted, medium hard; some clay in colloidal suspension, poorly water-bearing--	22	325
Gravel, fine to coarse; and sand, very coarse; clayey, arkosic, light buff, medium soft, poorly water-bearing--	3	328
Sand, fine to very coarse, slightly silty, clayey, gravelly, light buff, medium soft, in part water-bearing--	10	338
Gravel, fine to coarse; and sand, fine to coarse, silty to clayey, brown-gray to buff, soft; some colloidal clay, water-bearing----------------------	3	341
Sand, fine to very coarse, silty to clayey, slightly gravelly, gray-buff, medium hard, poorly water-bearing but soft and water-bearing below 356 feet--	22	363
Gravel, fine to coarse; and sand, fine to coarse, somewhat silty, arkosic, light gray-buff to white, soft, water-bearing----------------------------------	4	367
Sand, fine to very coarse, gravelly, and clayey to silty, buff, relatively compact, partly water-bearing---	33	400

2/7-3A1. Altitude 2,300.9 ft. Drilled by F.W. Walker in 1953. 16-inch casing 0-200 ft., 12-inch casing 200-560 ft. with bullnose at 560 ft. Gravel packed 0-560 ft. Materials logged by driller.

Sand, hard "shells,"[a/] and thin streaks of clay-----------	20	20
Coarse sand and gravel, and thin "shells"----------------	60	80
Cobbles and coarse sand----------------------------------	10	90
Sand and streaks of sandy clay---------------------------	15	105
Sand and "shells"--	25	130
Hard "shells" and coarse sand----------------------------	18	148
Coarse sand--	92	240
Sandy yellow clay, streaks of sand-----------------------	20	260
Sand, "shells," and cobbles------------------------------	35	295
Very hard "shells"---------------------------------------	5	300
Sandy yellow clay, coarse sand, and "shells"-------------	20	320
Sand and streaks of yellow sandy clay--------------------	42	362
Hard "shells"--	3	365

	Thickness (feet)	Depth (feet)
2/7-3A1. continued		
Sand, cobbles, and thin "shells"-------------------------	25	390
Coarse sand and cobbles----------------------------------	30	420
Coarse sand, cobbles, and "shells"-----------------------	96	516
Hard "shells"--	4	520
Sand, thin "shells," and cobbles-------------------------	40	560
Sand, and streaks of yellow sandy clay-------------------	30	590
Sand, and thin streaks of yellow sandy clay--------------	95	685
Sand, cobbles and yellow sandy clay----------------------	15	700
Coarse sand--	60	760
Hard packed sandy clay-----------------------------------	10	770
Coarse sand--	30	800

a. "Shells" refers to thin cemented beds.

2/7-14K1. Altitude 2,432.1 ft. Drilled by Mogle Bros. in 1952. 10-inch casing, perforated 450-525, 538-548, 550-558 ft. Cement plug at 644 ft.

Soil, sandy, loose, gray-brown---------------------------	2	2
Clay, fine to coarse sandy, very hard, red=brown; veinlets of calcium carbonate-----------------------	32	34
Sand, fine to very coarse, clayey; some small (½-inch) pebbles; fairly hard, red-brown; color change to gray-brown and no clay present at 47 feet---	54	88
Sand, fine to medium, some very coarse; occasional cobbles to 3 inches; fairly soft, gray-brown--------	20	108
Sand, very fine to very coarse, hard, gray-brown; silty clay streaks from 108 to 112 feet, and generally more fine material from 122 to 160 feet---	80	188
Sand, fine to very coarse, and gravel to 2 inches; soft, gray-brown------------------------------------	4	192
Sand, very fine to very coarse, clayey; streaks of very coarse sand and gravel to ½ inch; hard, gray-brown; some veinlets of white calcium carbonate--	12	204
Sand, medium to coarse, and some very coarse, very hard, medium gray, fairly well sorted---------------	12	216
Sand, very fine to very coarse; some pebbles to ½ inch; hard, gray-brown; streaks of very hard silty fine sand from 216 to 220 feet; some gravel to 1 inch; softer from 230 to 240 feet--------------	24	240
Sand, fine to very coarse, and gravel and boulders larger than 5 inches; hard, gray-brown; calcium carbonate crystals (calcite) well developed in vesicles of basalt cobble---------------------------	10	250
Sand, very fine to medium and some very coarse, silty, hard, gray-brown----------------------------	4	254

	Thickness (feet)	Depth (feet)
2/7-14K1. continued.		
Clay (interstitial); sand, mostly medium to very coarse, some fine to medium; and gravel, mostly fine, occasional cobbles; fairly soft; light gray-brown--	8	262
Clay, very sandy, mostly fine to medium, a little coarse, fairly soft, medium gray-brown--------------	4	266
Sand, coarse to very coarse, with some clay; fairly soft, light gray-brown------------------------	4	270
Sand, mostly coarse to very coarse, some medium; gravel, very fine to fine; and clay, interstitial; fairly soft, light gray-brown-----------------------	4	274
Sand, mostly coarse to very coarse; considerable gravel, very fine to medium; and some cobbles; fairly soft, light gray-brown------------------------	15	289
Sand, mostly medium, some fine and coarse; with a little very fine gravel; and much interstitial clay; rather hard; plastic and cohesive when wet; light gray-brown. Sand finer and gravel absent 298 to 308, 326 to 329, and 331 to 335 feet. Slight increase in clay, and gravel coarser (fine to medium) 308 to 326 and 329 to 331 feet-----	46	335
Sand, mostly medium to very coarse; and gravel, mostly very fine to medium, some cobbles to 2 inches; fairly soft, gray-brown-------------------	4	339
Sand, fine to coarse; some clay and silt; and a little gravel 339 to 346 feet; fairly soft, gray-brown---	11	350
Sand, mostly medium to very coarse; and gravel, mostly very fine to medium, some to 2 inches; occasional thin clayey streaks; fairly soft, light gray-brown. Less and finer gravel 368 to 388 feet-------------------------------------	38	388
Sand, mostly medium to very coarse, some fine to medium; gravel, mostly fine, a few small cobbles; clay, interstitial, apparently fills much of pore space, comes up in large chunks, plastic when wet, hard when dry, increasingly micaceous below 420 feet; rather soft, medium gray-brown. Drilling water has peculiar milky appearance and feels soapy; probably contains bentonite. Encountered first water at 424 feet; rose rapidly to 340 feet. No discernible change in formation; beds below 424 feet may be clean sands and gravels alternating with clayey sands and gravels--	61	449

	Thickness (feet)	Depth (feet)
2/7-14K1. continued		
Sand, mostly coarse to very coarse, some medium to coarse; and considerable gravel, mostly fine, some medium; contains some maroon basalt pebbles largely altered to clay; rather soft, yellowish-gray-brown, good water-bearing material. Drilling water continues milky. From 510 to 553 feet quantity and size of gravel varies slightly in beds 3 to 10 feet thick and drilling water somewhat more milky; occasional clay streaks 543 to 558 feet----------------------	109	558
Clay, containing much sand, very fine to very coarse, and a little fine gravel from 558 to 598 feet; pale lavender-brown from 558 to 575 feet, becoming increasingly darker yellow-brown below; moderately to strongly calcareous, and occasionally cemented, quite hard. Drilling water is very milky. Streak of loose, coarse sand and medium gravel encountered at 638 to 639 feet--	86	644

NOTE: Sand grains are predominantly quartz and feldspar, with minor amounts of biotite, magnetite, and granitic minerals; subangular to subrounded. Gravel and cobbles largely gneiss and granitics, with few basalt and some metamorphic rocks; subrounded to rounded.

3/7-13N1. Altitude 2,020.2 ft. Drilled by Mogle Bros. in 1952. 10-inch casing, perforated 280-293, 305-317, 345-389, 416-426, 450-460, and 480-487 ft.

Sand, fine to coarse; occasionally silty, some thin lenses of caliche; some thin lenses of fine to medium gravel; buff to tan, soft. No real soil or soil profile; grains are fresh-------------------	18	18
Sand, fine to very coarse, mostly coarse; and gravel, mostly fine to medium, some coarse, some cobbles up to 6 inches; medium to light grayish-brown, soft to hard due to compaction, no cemented grains found. Interbedded calcareous, whitish clay from 76 to 78 feet. Some cementation and large cobbles up to 8 inches from 85 to 86 feet. Generally less coarse from 93 to 96 feet---------------------	94	112
Sand, fine to coarse, mostly fine; and considerable clay and silt; gray-brown to brown, calcareous, hard---	4	116

	Thickness (feet)	Depth (feet)
3/7-13N1. continued.		
Sand, fine to very coarse, mostly very coarse; and gravel, mostly fine; grayish brown, moderately hard, partially water-bearing. Some medium to coarse gravel 143 to 144 feet; some caliche at 160 feet; considerable biotite and magnetite giving a dark grayish color to the cuttings 173 to 179 feet; cemented sand and gravel at 191 feet; coarse gravel 194 to 195 feet-----------------	84	200
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; some small cobbles; gray-brown, soft, water-bearing----------------------------------	20	220
Sand, fine to coarse, mostly coarse; and considerable fine gravel, some medium; gray-brown, moderately soft, water-bearing----------------------------------	57	277
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; occasionally calcareous, gray-brown, soft, water-bearing. Mostly fine but little tan coarse gravel 293 to 303 feet; some cobbles up to 4 inches 303 to 318 feet-------------------------	41	318
Sand, fine to coarse. mostly fine to medium, gray-brown, soft, water-bearing---------------------	8	326
Sand, fine to coarse, mostly fine to medium, considerable biotite, dark brownish-gray, soft, water-bearing----------------------------------	10	336
Sand, fine to coarse, mostly coarse; and gravel, mostly fine to medium, with some coarse; gray-brown to gray, soft, water-bearing. Cemented sand and gravel 381 to 382 feet---------------------	53	389
Sand, fine to coarse, mostly fine, with considerable silt and clay, dark grayish-brown, soft, partially water-bearing--	8	397
Sand, fine to coarse, mostly coarse; and gravel, mostly fine, with some medium to coarse; gray-brown, soft, water-bearing. Considerable amounts of medium and coarse gravel 401 to 407, 411 to 414, and 416 to 426 feet----------------------------------	29	426
Sand, fine to coarse; and some gravel, mostly fine; gray-brown, soft, water-bearing---------------------	22	448
Sand, fine to coarse, mostly coarse; gravel, fine to coarse; and some cobbles up to 6 inches; light grayish-brown, soft, water-bearing. Considerable basalt gravel and cobbles from 456 to 458 feet------	11	459
Sand, fine to coarse; and some fine gravel; cemented, calcareous, gray-brown, hard, partially water-bearing--	19	478
Sand, fine to coarse, mostly coarse; and gravel, fine to coarse; gray-brown, soft, water-bearing. Somewhat cemented 479 to 481 feet------------------	9	487

	Thickness (feet)	Depth (feet)
3/7-13N1. continued.		
Sand, fine to coarse, silty, cemented, considerable biotite, dark brownish-gray, hard, partially water-bearing--	9	496
Sand, fine to coarse, mostly coarse; and gravel, mostly fine to medium, some coarse; partially cemented, gray-brown, moderately soft, water-bearing. Bail test indicates bottom-hole material very good water-bearing formation----------------------------	5	501

NOTE: Sands, largely quartz and feldspar with varying amounts of magnetite, biotite (phlogopite), grains subrounded to angular and poorly sorted, color is largely gray-brown, but is commonly gray when there is considerable biotite and magnetite. Gravels and cobbles are largely altered and unaltered granitics with gneiss and granite (?) with some basalt, and quartzite, usually subrounded to rounded.

3/7-31E1. Altitude 2,514.3 ft. Drilled by Mogle Bros. in 1952. 10-inch casing 0-418 ft, uncased hole 418-430 ft, perforated 300-328, 340-401 ft.

	Thickness (feet)	Depth (feet)
Soil, fine to very coarse sandy and gravelly, brown, fairly hard---------------------------------	3	3
Caliche (calcium carbonate), white, very hard------------	2	5
Sand, fine to very coarse, and some gravel to 3 inches, gray-brown, hard; boulders to 20 inches and thin caliche (calcium carbonate) layers from 5 feet to 7 feet; no gravel from 40 feet to 44 feet--	39	44
Clay, very fine to very coarse sandy, brown, very hard---	36	80
Sand, very fine to very coarse, silty, brown, fairly hard, calcium carbonate cement----------------------	3	83
Clay, very fine to very coarse sandy, brown, hard--------	5	88
Sand, very fine to very coarse, and gravel to 4 inches, brown, fairly soft--------------------------	4	92
Clay, silty, and very fine to very coarse sandy, brown, hard--	32	124
Clay, silty and fine sandy, brown, fairly soft; contains black organic material and some iron stains--	2	126
Clay, silty and fine sandy; some coarse sand; brown, fairly hard; contains some caliche (white calcium carbonate), more coarse to very coarse brittle sand from 186 to 210 feet---------------------------	84	210
Sand, very fine to very coarse; some silty clay; gray-brown, hard, cemented; fine to coarse brown sandy clay from 214 to 215 feet------------------------	14	224

3/7-31E1. continued.	Thickness (feet)	Depth (feet)
Sand, fine to coarse; occasional gravel; and cobbles up to 5 inches; gray, fairly hard, partially cemented	20	244
Sand, very fine to very coarse; occasional gravel; and cobbles up to 5 inches; gray, soft; pebbles smaller, to ½ inch, and more silty from 328 feet to 338 feet; very hard, round, fine to coarse sand concretions from 340 to 358 feet; partially cemented and fairly hard from 358 feet to 392 feet; in part water-bearing	148	392
Sand, fine to coarse, and some gravel with boulders larger than 10 inches; gray, very hard drilling; at least partially cemented with an extremely hard calcareous cement; calcite(?) or crystal approximately 1 inch long observed on cobble recovered from 410 feet; gray, fine to coarse sand heaves in hole from 415 feet to 415 feet 6 inches; in part water-bearing	38	430

3/8-17L1. Altitude 1,850.4 ft. Drilled by Mogle Bros. in 1952. 10-inch casing, perforated 248-258, 272-300, 374-380, 396-408, 410-416, and 444-456 ft. Cement plug at 512 ft.

Soil, sandy to silty, light brown, hard	8	8
Sand, fine to coarse, light buff, soft	4	12
Clay, calcareous, plastic, sticky, light gray	12	24
Gravel, medium to fine, and some sand	1	25
Clay, red- to yellow-brown, plastic	3	28
Sand, very fine to coarse, light buff, soft; few pebbles	5	33
Sand and clay, with layers of fine sand and silty clay, gray	21	54
Sand, fine, silty, few coarse grains, micaceous, yellow-gray	19	73
Clay, sandy, silty, yellow-gray, hard	6	79
Sand, fine, silty, yellow-brown	14	93
Sand, largely fine, silty, yellow, brown, gray, and lavender streaks; medium and coarse fraction increasing with depth	29	122
Sand, silty, soft to hard; proportion of sand greatly increased over that from 93 to 122 feet	19	142
Gravel, fine to very coarse, and sand, fine to coarse	3	145
Sand, very fine, silty, hard, a few concretions, gray	43	188
Clay, very fine sandy, dark brown, plastic, hard; some white $CaCO_3$ layers	1	189
Sand, fine to coarse, silty, some pebbles ½-inch, olive green, hard; iron stains abundant; yellow-green from 189-190	3	192

	Thickness (feet)	Depth (feet)
3/8-17L1. continued.		
Sand, coarse to very coarse, and gravel to ½-inch; streaks of fine sandy clay; light brown, fairly soft	4	196
Sand, very fine to medium, silty; some coarse sand-streaks, and some clay; light brown, hard; some layers of cemented ($CaCO_3$) sand	36	232
Sand, coarse to very coarse, and gravel to 1-inch, red-brown, soft	4	236
Clay, fine to very coarse sandy, and some pebbles to ¼-inch; dark brown, extremely hard; white $CaCO_3$ fragments	12	248
Sand, coarse to very coarse; and gravel to 3 inches; few streaks of silty sand; light brown, soft, some $CaCO_3$ cementing; water-bearing	10	258
Sand, very fine to very coarse, silty; some gravel to 1-inch; medium brown, hard. Gray, green, violet, and red colors 258 to 259 feet	14	272
Sand, coarse to very coarse, some fine to medium, and gravel to 6 inches, buff, soft; heaves up in hole; water-bearing	28	300
Sand, coarse to very coarse, some fine to medium; some gravel to 1-inch; buff, soft; heaves up in hole; gray-brown from 320 to 332 feet	32	332
Sand, fine to medium, dark brown-gray, firm; some 1-inch gravel from 332 to 340 feet; some fine sandy clay streaks 346 to 360 feet	28	360
Sand, very fine silty to some very coarse, and clay; dark gray-brown, fairly hard; hard iron-stained light brown clay 360 to 362 feet; hard light brown clay and ½-inch gravel 373 to 374 feet	14	374
Sand, medium to very coarse, and gravel to 3 inches, light brown to buff, soft; heaves up in hole; water-bearing	6	380
Sand, medium to very coarse, some gravel to 2 inches, and streaks of clay; brown-buff, soft; cemented ($CaCO_3$) 390 to 396 feet	16	396
Sand, medium to very coarse, and gravel to 3 inches, gray to buff, soft; some $CaCO_3$ cemented sand and gravel; clayey fine to coarse sand with red-brown, very hard, white $CaCO_3$ stringers from 408 to 410 feet; water-bearing	20	416
Sand, medium to very coarse, occasional gravel to 2 inches, brown-buff, soft; gravel to 4 inches, 444 to 456 feet; water-bearing; many cemented ($CaCO_3$) fine to coarse sand concretions, gray-brown, very hard from 499 to 510 feet	94	510
Sand, fine to very coarse, cemented, gray-brown, hard	2	512

3/8-29L1. Altitude 1,905.7 ft. Drilled by F.W. Walker in 1952. 16-inch casing 0-250 ft, 12-inch casing 250-600 ft. with bullnose at 600 ft. Uncased pilot hole 600-800 ft. Perforated 270-590 ft. Gravel packed 0-600 ft. Materials logged by driller.

	Thickness (feet)	Depth (feet)
Surface soil and and	10	10
Coarse sand and cobbles up to 2 inches in diameter, some basalt cobbles	10	20
Coarse sand	10	30
Sand and gravel	10	40
Coarse sand	25	65
Fine sand, hard; cobbles at 110 feet	45	110
Coarse sand	20	130
Hard packed sand	20	150
Coarse sand and hard "shells"[a]	40	190
Coarse sand	55	245
Hard packed sand	5	250
Coarse sand	35	285
Coarse sand and hard "shells"	41	326
Hard packed sand	20	346
Coarse sand	23	369
Hard packed sand	11	380
Cobbles and hard sandy "shells"	10	390
Coarse sand	45	435
Hard sand and "shells"	15	450
Coarse sand	20	470
Fine sand	10	480
Sandy yellow clay	20	500
Coarse sand	15	515
Hard-packed fine sand	8	523
Sandy yellow clay	7	530
Sand	20	550
Yellow sandy clay	20	570
Cobbles	2	572
Coarse sand	38	610
Sandy yellow clay	10	620
Coarse sand	15	635
Yellow sandy clay	55	690
Coarse sand	20	710
Sandy clay	20	730
Sandy yellow clay and streaks of coarse sand	30	760
Coarse sand and streaks of yellow sandy clay	40	800

a. "Shells" refers to thin cemented beds.

3/8-34D1. Altitude 1,823.9 ft. Drilled by Mogle Bros. in 1943. 12-inch casing, perforated 186-210, 270-290, 360-370, 384-396 ft. Materials logged by driller.

	Thickness (feet)	Depth (feet)
Drift sand	6	6
Sandy clay	44	50
Coarse water sand and rock	20	70
Yellow clay	10	80
Quicksand	55	135
Coarse sand and small gravel	10	145
Packed silt and fine sand	41	186
Coarse water sand	24	210
Fine silt and sand	28	238
Coarse sand and fine gravel	10	248
Clay and sand	8	256
Cemented sand	14	270
Coarse sand and rock	20	290
Packed silt and cement	70	360
Coarse water sand	10	370
Packed silt	14	384
Coarse water sand	12	396
Packed silt	4	400

4/6-18F1. Altitude about 2,292 feet. Drilled by U.S. Geological Survey in 1953. Uncased 4-inch auger hole.

Hard brown lake clay, slightly moist below 4 inches	4.8	4.8
Caliche	.1	4.9
Decomposed granitic sand, coarse sand and very fine gravel	.5	5.4
Fine sand	1.8	7.2
Coarse silt	1.3	8.5
Clayey silt, dark brown	.1	8.6
Silt and fine sand	2.7	11.3
Clay, sand and silt	.3	11.6
Silt and fine sand, somewhat softer	1.2	12.8
Clay, silt and very fine sand	.2	13.0
Silt and very fine sand, almost dry	.3	14.0
Silt, very fine sand, streak of clay, mosit	3.3	17.3
Clay and silt becoming more moist	.3	17.6
Plastic clay, quite moist	4.4	22.0
Plastic clay, olive green, moist	1.4	23.4
Clay, olive-green, streaks and chunks of black carbonaceous material	.6	24.0
Carbonaceous clay, black	8.2	32.2
Carbonaceous clay, black with streaks of blue	.4	32.6
Medium sand, yellowish green	.9	33.5
Clay, black with streaks of blue	3.7	37.2
Clay, blue	1.9	39.1

Table B IV. Chemical analyses of water from wells on or near the Marine Corps Training Center, Twentynine Palms, California

<u>Constituents</u>: Values shown in parentheses were calculated.

Well number	IN/9E-4N3	IN/9E501
Constituents in parts per million		
Silica (SiO_2)	--	--
Iron (Fe)	--	--
Calcium (Ca)	28	33
Magnesium (Mg)	3	4.7
Sodium (Na)	180	200
Potassium (K)	3	4.8
Bicarbonate (HCO_3)	98	76
Carbonate (CO_3)	0	0
Sulfate (SO_4)	294	(343)
Chloride (Cl)	66	74
Fluoride (F)	6	7.2
Nitrate (NO_3)	1	--
Boron (B)	0.26	--
Dissolved solids	666	--
Sum of determined constituents	(624)	(704)
Hardness as $CaCO_3$	82	102
Percent sodium (%Na)	(82)	(80)
Specific conductance (micromhos at 77 F)	936	1,070
pH	8.2	6.8
Temperature (F)	64	--
Date collected	4-15-52	5-3-60
Depth of well in feet	500	500
Analyzing laboratory (Lab.)	DWR	GS
Laboratory number	1835	33852

Well number	2/7-2C1		2/7-3A1	
Constituents in parts per million				
Silica (SiO_2)	18	18	24	
Iron (Fe)	0	.05	.1	
Calcium (Ca)	3	11	9	12
Magnesium (Mg)	0	.5	1	.5

Sodium (Na)	a(50)	44	a(44)	47
Potassium (K)		2.1		2.2
Bicarbonate (HCO_3)	51	82	68	69
Carbonate (CO_3)	17	0	5	0
Sulfate (SO_4)	24	30	29	(46)
Chloride (Cl)	12	20	18	22
Fluoride (F)	1.1	1.0	.9	.8
Nitrate (NO_3)		1.5		
Boron (B)	.3	.12	.06	
Dissolved solids	140	172	185	
Sum of determined constituents	(150)	168	(164)	(164)
Hardness as $CaCO_3$	7	30	26	32
Percent sodium (%Na)	(94)	75	(78)	75
Specific conductance (micromhos at 77°F)		270		306
pH	9.0	8.6	8.8	7.9
Temperature (°F)	93	84.5	84.5	82
Date collected	4-21-52	2-3-53	2-24-53	5-4-54
Depth of well in feet	400	560	560	560
Analyzing laboratory (Lab.)	N	GS	N	GS
Laboratory number (No.)	1492	6210	4	11,154

Well number		2/7-3A1--continued		
Constituents in parts per million				
SiO_2				
Fe				
Ca		11		12
Mg		.5		.5
Na		45		47
K		1.9		2.3
HCO_3		86		86
CO_3		0		0
SO_4		(29)		(34)
Cl	20	19	20	21
F		.4		.7
NO_3		1.9		
B		.06		
Dis. S				
Sum		(151)		(160)
Hardness	32	30	33	32

%Na		75		74
Micromhos	276	284	278	285
pH		7.2		
°F	82	81	79	80
Date	5-18-55	10-17-55	3-5-57	5-14-58
Depth	560	560	560	560
Lab.	GS	GS	GS	GS
No.	15,348	18,237	21,833	25,927

Well number	2/7-3A1--Continued			
Constituents in parts per million				
SiO_2				
Fe				
Ca		12	12	11
Mg		1.0	.2	1.2
Na		52	47	48
K		1.8	2.1	2.8
HCO_3		85	87	90
CO_3		0	0	0
SO_4		(47)	(31)	34
Cl		21	21	21
F		.8	.7	.8
NO_3				
B				
Dis. S				
Sum		(178)	(157)	(163)
Hardness		34	31	32
%Na		76	75	74
Micromhos		292	261	287
pH		7.0	7.4	6.9
°F		81	81	
Date		10-8-58	4-7-59	5-4-60
Depth		560	560	560
Lab.		GS	GS	GS
No.		28,224	30,073	

Well number	2/7-3B1			
Constituents in parts per million				
SiO_2	22			
Fe	0			
Ca	12		13	12
Mg	0		.4	.1
Na	a57		53	52
K			2.2	3.2

HCO_3	58		83	88
CO_3	9.6		0	0
SO_4	46		(42)	(38)
Cl	30	29	28	24
F	.4		.4	.6
NO_3				
B	.09			
Dis. S	235			
Sum	(206)		(180)	(173)
Hardness	30	35	34	31
%Na	81		76	77
Micromhos	316	307	313	300
pH	8.6		6.8	6.9
°F		80	82	
Date	9-11-56	3-6-57	10-8-58	5-4-60
Depth	700	700	700	700
Lab.	N	GS	GS	GS
No.		21,834	28,225	33,855

Well number	2/7-3B1. continued			
Constituents in parts per million				
SiO_2	21	23		
Fe	.1	.1		
Ca	9	11	15	16
Mg	1	1	2.1	.2
Na	a(44)	a(52)	52	54
K			2.6	2.7
HCO_3	68	61	83	93
CO_3	5	7	0	0
SO_4	29	40	(50)	(40)
Cl	18	28	29	30
F	.9	.5	.6	.7
NO_3				
B	.06	.06		
Dis. S	196	210		
Sum	194	(193)	(192)	(190)
Hardness	38	32	46	41
%Na	72	(78)	70	73
Micromhos	311		325	346
pH	8.4	8.8	8.5	8.0
°F	82	82	81.5	
Date	1-15-53	2-24-53	5-4-54	12-21-54
Depth	700	700	700	700
Lab.	GS	N	GS	GS
No.	6209	3	11,153	14,949

Well number	2/7-4H1	2/7-14K1	2/8-11-B1	2/8-24H1	3/6-4L1
Constituents in parts per million					
SiO_2	25	20		10	18
Fe	0			.1	0
Ca	12	2	4.3	8	38
Mg	1	1	4.7	1	9
Na	a(43)	a(57)	1,720	a(181)	a(39)
K			8.6		
HCO_3	76	73	1,340	22	168
CO_3	1	24	187	10	0
SO_4	39	15	(1,170)	258	42
Cl	15	10	725	66	30
F	.7	1.1	50	8	5
NO_3					
B	.1			.52	.08
Dis. S	164	154		580	230
Sum	(174)	(166)	(4,530)	(554)	(264)
Hardness	35	8	30	26	132
%Na	(73)	(93)	99	(94)	(39)
Micromhos			7,010		
pH	8.5	8.9	9.0	8.9	7.9
^oF	80	96	71	85	
Date	9-30-52	9-29-52	5-1-53	3-11-52	12-5-51
Depth	500	644	64.6	320	137
Lab.	N	N	GS	N	N
No.	8	1589	7357	1458	

Well number	3/6-4P1	3/7-13N1	3/7-18D1	3/7-31E1
Constituents in parts per million				
SiO_2		24	16	16
Fe		0	0	0
Ca	20	52	56	10
Mg	3.5	5	11	2
Na	49	a(173)	a(81)	a(42)
K	2.5			
HCO_3	148	93	76	81
CO_3	0	0	0	4
SO_4	(19)	245	120	25
Cl	22	136	122	17
F	.7	1.6	.3	.5
NO_3				
B		.14	.24	.01
Dis. S		640	430	140
Sum	(190)	(683)	(444)	(157)
Hardness	64	150	184	34

%Na	61	(72)	(49)	(74)
Micromhos	356			
pH	8.2	8.2	7.7	8.4
°F		83	74	78
Date	1-29-53	8-8-52	5-1-52	8-8-52
Depth	132	501	449	430
Lab.	GS	N	N	N
No.	6602	1560	1500	1557

Well number	3/7-35P1		3/8-17L1	3/8-29C1
Constituents in parts per million				
SiO_2	18		16	18
Fe	0		.1	0
Ca	6	6.8	20	33
Mg	1	.2	3	5
Na	a(56)	50	a(318)	a(258)
K		4.2		
HCO_3	83	96	76	90
CO_3	2	0	4	0
SO_4	36	(21)	268	298
Cl	18	20	280	196
F	2.5	1.0	4	1.5
NO_3				
B	.12		.7	.7
Dis. S	120		980	860
Sum	(181)	(150)	(951)	(854)
Hardness	20	18	62	102
%Na	(86)	82	(92)	(84)
Micromhos		271		
pH	8.2	7.0	8.3	8.0
°F			83	85
Date	12-5-51	5-1-53	3-18-52	6-12-52
Depth	--	--	512	800
Lab.	N	GS	N	N
No.		7358	1479	1515

Well number			3/8-29L1		
Constituents in parts per million					
SiO_2	18	18			
Fe		0			
Ca	46	46	48		48
Mg	4.6	5	2.1		1.3
Na	305	a(305)	300		296
K	5.6		5.1		5.6

HCO_3	78	63	78		80
CO_3		4	0		0
SO_4	407	427	(391)		(385)
Cl	215	202	215	212	211
F	3.6	4.5	5	4.8	4.8
NO_3	1.0				
B	.67	1.0			
Dis. S	1,040	1,000			
Sum	(1,040)	(1,040)	(1,000)		(991)
Hardness	134	136	128		125
%Na	82	(83)	83		83
Micromhos	1,690		1,680	1,710	1,660
pH	7.9	8.3	8.0		7.2
^oF	79	80	79	79.5	79.5
Date	12-13-52	12-22-52	5-5-54	10-21-54	4-16-55
Depth	600	600	600	600	600
Lab.	GS	N	GS	GS	GS
No.	5986	1	11155	14947	14948

Well number			3/8-29L1--Continued		
Constituents in parts per million					
SiO_2		6	20		
Fe		4.5			
Ca	44	40	37	46	44
Mg	3.3	6	5	2.4	3.6
Na	297	442	a271	283	303
K	4.5	4.5		4.0	5.6
HCO_3	40	70	83	88	80
CO_3	0	5	0	0	0
SO_4		340	360	(342)	(403)
Cl		296	186	216	210
F	5.0	6.0	5.0	5.0	4.0
NO_3	.6	.1			
B	1.3	.83	1.2		
Dis. S		1,200	952		
Sum		(1,180)	(926)	(941)	(1,010)
Hardness	124	100	114	125	125
%Na	83	90	84	83	83
Micromhos	1,630	1,700	1,570	1,620	1,630
pH	6.8	8.3	7.9	7.7	7.1
^oF	80			80	80
Date	10-17-55	4-4-56	9-11-56	2-8-57	5-14-58
Depth	600	600	600	600	600
Lab.	GS	N	N	GS	GS
No.	18238			21602	25926

Well number	3/8-29L1--Continued	
Constituents in parts per million		
SiO_2		
Fe		
Ca	43	47
Mg	3.0	4.5
Na	294	307
K	2.0	9.8
HCO_3	83	92
CO_3	0	0
SO_4	(374)	(415)
Cl	207	210
F	5.0	4.8
NO_3		
B		
Dis. S		
Sum	(969)	(1,040)
Hardness	120	136
%Na	84	82
Micromhos	1,620	1,630
pH	6.8	6.7
°F	79	
Date	10-8-58	5-4-60
Depth	600	600
Lab.	GS	GS
No.	28223	33853

Well number:	3/8-33B1	3/8-34D1	4/6-27C1	4/6-27D1	4/6-27F1	4/6-27M1
Constituents in parts per million						
SiO_2	18	18				
Fe	.1	0				
Ca	50	23	27	b13.6	b4	128
Mg	8	3	12			21
Na	a(268)	a(280)	790	206	790	160
K			5.8	2.0	4.9	4.7
HCO_3	85	103	640	12	568	112
CO_3	0	4	43	252	421	0
SO_4	381	276	a(562)	(9)	(173)	(257)
Cl	188	204	465	164	88	282
F	4	4.5	1.9	6.4	100	.9
NO_3						
B	1.1	1.2				
Dis. S	830	870				
Sum	(960)	(865)	(2,230)	(523)	(1,860)	(257)
Hardness	160	72	117	34	10	406

%Na	(79)	(90)	93	92	99	46
Micromhos			2,710	997	3,170	1,560
pH	8.0	8.2	8.8	8.6	9.7	7.8
°F	72	74				
Date		4-2-52	1-29-53	1-29-53	1-29-53	6-10-53
Depth	526	400	63	80.2	182.3	150
Lab.	N	N	GS	GS	GS	GS
No.	1445	1485	6603	6605	6604	7359

b. Includes magnesium.

APPENDIX II-C.

CHINA LAKE SITE

Table CI. Factual data on test wells drilled on Naval Weapons Center, China Lake, California.

State Well Number	Altitude (feet)	Depth (feet)	Type of well and diameter (inches)	Measuring point (feet)	Water level Date	Water level (feet)
25N/40E-33L2	2,171.0	22.2	RG8	TcN 1.8	3- 8-54	2.01
					4-15-54	1.96
					5-13-54	2.14
25N/41E-28B1	2,238.6	161.8	R 8	TcE 1.5	3-10-54	68.84
					3-16-54	67.58
					4-15-54	67.60
					5-13-54	67.66
26N/40E-1A2	2,157.6	197.5	R 6	TcE 1.7	3- 9-54	+0.98
					4-15-54	+1.39
					5-13-54	+1.45
26N/40E-1A3	2,157.6	18.5	A 1¼	TcE 1.9	4-15-54	8.92
					5-13-54	8.72
26N/40E-22P1	2,258.7	850.0*	R 8	TcS 1.5	3- 8-54	64.39
					4-16-54	64.36
					5-13-54	64.28
26N/40E-24R1	2,260.4	149.1	R 6	TcS 1.2	3- 9-54	74.59
					4-15-54	74.15
					5-13-54	74.06
26N/40E-36A1	2,247.2	270.0	R 6	TcN 1.5	3- 9-54	56.82
					4-15-54	56.84
					5-13-54	56.85
26N/41E-7G2	2,181.3	49.3	R 6	TcN 1.2	3- 3-54	36.42
					3-16-54	36.40
					4-15-54	36.38
					5-13-54	36.36

*Well drilled to 1,358 feet, concrete plug from 850 to 875 feet.

Table C 11. Logs on test wells drilled on Naval Weapons Center, China Lake, California.

	Thickness (feet)	Depth (feet)
25/40-33L2. Perforated from 2 to 22 feet. Altitude 2,171.0 feet.		
Sand, subangular to subrounded, poorly sorted, fine to coarse, loose, and a little very fine gravel	2	2
Sand, medium, uniform, loose	7	9
Sand, medium to coarse, angular	1	10
Sand, medium to coarse, with a little clay	4	14
Sand, medium to coarse, and very fine gravel	2	16
Sand, coarse, subangular to subrounded and very fine gravel, with some clay	3	19
Sand, medium to coarse, angular, with a little silty clay and subrounded fine gravel	1	20
Sand, medium to coarse, with increase in silty clay	2	22
25/41-28B1. Perforated from 127 to 161.8 feet. Altitude 2,238.6 feet.		
Sand, wind-blown	6	6
Sand, gravel and white silty clay	4	10
Sand, coarse, and fine gravel	4	14
Sand and gravel	9	23
Sand	11	34
Sand with plastic clay	2	36
Gravel	1	37
Gravel with clay	1	38
Boulder	1	39
Sand, coarse	27	66
Sand, reddish, stained by oxidation	3	69
Boulder	1	70
Sand	3	73
Sand and gravel	3	76
Sand and white clay	3	79
Sand, some grains oxidized	9	88
Sand with blue clay and white silt	7	95
Boulder	1	96
Silt, white, and sand	4	100

	Thickness (feet)	Depth (feet)
25/41-28B1. Continued.		
Silt, white; sand and gravel	5	105
Silt, white; sand; gravel and blue clay	10	115
Silt, white, sandy, soft, and coarse sand	14	129
Silt, white, sandy, soft, gradually becoming gray, with increase in coarse sand	10	139
Sand, coarse, and pea gravel	3	142
Sand, medium to coarse, and gray to gray-blue clay	13	155
Transition zone	4	159
Bedrock	3	162
26/40-1A2. Perforated from 80 to 100, 110 to 130, 170 to 190 feet. Altitude 2,157.6 feet.		
Clay, pale green, plastic; and gray clay	30	30
Clay, black, carbonaceous, with about 10% medium sand	10	40
Clay, dark gray to black, plastic, with olive-green very fine silt and some waxy clay. Gastropod shells and H_2S odor	9	49
Sand, moderately well consolidated, calcareous, fairly hard	1	50
Clay, black, plastic, with small amount of subrounded, moderately well consolidated medium to coarse, calcareous sand	20	70
Clay, gray, plastic, and black, pyritic sandy, carbonaceous clay with numerous chips of calcareous material and some partly carbonized wood. Strong H_2S odor	10	80
Sand, fine to medium, argillaceous, with some calcareous material	10	90
Sand, fine, moderately well cemented; and a little rounded coarse sand	1	91
Sand, gray, silty, with some clay and streaks of moderately well cemented fine to medium calcareous sand. Gastropods	9	100
Silt, argillaceous, finely sandy; black when wet dark green when dry; with calcareous chips. Strong H_2S odor	10	110
Sand, gray, subangular to subrounded, silty, fine to medium, plus a little white calcareous sand, moderately well cemented	10	120
Sand, fine to medium, gray-white, subrounded, slightly calcareous, fairly hard, silty	9	129

26/40-1A2. Continued.	Thickness (feet)	Depth (feet)
Clay, sandy, gray and black clay	11	140
Clay, sandy with chips of lime	4	144
Limy bed	2	146
Clay, black	14	160
Clay, silty gray to plastic	10	170
Sand, very coarse or very fine gravel	20	190
Clay, with some sand	7.5	197.5

26/40-1A3. Perforated from 13.9 to 18.5 feet. Altitude 2,157.6 feet		
Silt, cemented	1.0	1.0
Sand, fine, yellow	3.5	4.5
Sand, clayey, yellow	0.5	5.0
Silt, gray, with numerous shell fragments	1.0	6.0
Clay, gray plastic	2.5	8.5
Clay, finely sandy, slightly micaceous, moist olive-green	0.5	9.0
Clay, plastic, gray	3.0	12.0
Clay, plastic, gray-black	1.3	13.3
Clay, plastic, gray, soft and moist	0.2	13.5
Sand, clayey, moist	0.2	13.7
Clay, plastic, gray-blue	4.8	18.5

26/40-22P1. Perforated from 530 to 850 feet. Concrete plug from 850 to 875 feet. Altitude 2,258.7 feet.		
Sand, yellow, wind-blown and pebbles	2.5	2.5
Sand, fine to medium, angular, white, with pebbles to 3/4-inch	13	15.5
Sand, very fine, micaceous, with pumice (?)	17	32.5
Silt, sandy, fine, gray, soft, with shells	34	66.5
Clay, sandy, fine, gray-green, soft, plastic, with gastrapods	19	85.5
Clay, gray-green, very soft, with very little sand and no shells	16	101.5
Clay, soft, blue-green. No shells, no sand	31	132.5
Clay, soft, blue-green, with a little coarse sand and no shells	15	147.5
Silt, slightly sandy, very fine, and gray clay	15.5	163
Clay, soft, blue-green, with a few coarse sand grains	15.5	178.5
Clay, soft, plastic, blue-green with a very fine gravel	15.5	194
Calcareous material, hard	3	197
Clay, soft, plastic, gray-green, with rare very fine gravel	12.5	209.5

26/40-22P1. Continued	Thickness (feet)	Depth (feet)
Clay, firm, gray-green, mottled, micaceous, gritty	14.5	224
Clay, gray green, firm, with angular chips of gray tuff and some very fine gravel	30.5	254.5
Clay, silty, soft, gray-green and olive-green, with streaks of biotite-rich silty clay and a little fine gravel	15	269.5
Clay, soft, gray-green and olive-green, with some rounded very fine gravel, very little biotite, and some calcareous fragments	15	284.5
Clay, soft, gray-green and olive-green, with sand-size fragments of granite	48	332.5
Clay, gray-green, soft, with some coarse sand	12.5	345
Calcareous material, hard (Limestone?)	8	353
Clay, gray-green, soft, with sand and some shell	8.5	361.5
Calcareous material	2	363.5
No returns	43	406.5
Clay, sandy, blue-green, soft, with some sand, very fine gravel, calcareous fragments and shells	44	450.5
Clay, blue, with calcareous fragments and less sand	17	467.5
Clay, blue, with small pebbles and chips of lime	18	485.5
Clay, blue, with very coarse sand	40	525.5
Clay, blue, soft, with hard lime and sand streaks	38	563.5
Calcareous material, hard	4	567.5
Clay, sandy	7	574.5
Lime (?); hard streak	2	576.5
Clay, sandy	18	594.5
Gravel (?), very fine, hard	22	616.5
Sand, coarse, with lime and shell fragments	4	620.5
Sand with gastropods	15	635.5
Sand, medium-coarse, angular, with blue-green and gray-green, soft, crumbly clay and shell fragments	8	643.5
Sand, fine-coarse, angular	8	651.5
Sand, fine to medium, subrounded, with considerable biotite, some coarse sand, soft, blue, platy clay, and a few limy chips	15	666.5
Sand, coarse, angular, with some blue clay and a little fine sand	16	682.5
Sand, subrounded to subangular, very fine to fine, with rare biotite plus blue and gray non-plastic clay	16	698.5

26/40-22P1. Continued	Thickness (feet)	Depth (feet)
Sand, greenish-gray, argillaceous, subrounded, medium to coarse, with much biotite	14.5	713
Sand, fine and silty gray-green clay	16.5	729.5
Sand, fine, silty, micaceous, and clay	14.5	744
Sand, very fine, well-sorted, and silty, gray-green clay	62	806
Sand, fine and gray-green clay with chips of hard, green non-plastic clay	10.5	816.5
Sand, hard	5	821.5
Sand, silty, fine, with olive-green, non-plastic clay plus rare coarse sand	45	866.5
Sand, silty, green with increase in clay	30	896.5
Sand and sandy clay in alternating beds	31	927.5
Clay, plastic, blue-green, soft, gritty	26	953.5
Sand, hard	1	954.5
Sand, medium, fairly uniform, subangular to subrounded, with some plastic blue clay, silt and a little coarse angular sand	19	973.5
Sand, very fine, about 50%, with coarse, angular, micaceous, sand and a little plastic blue clay	15	988.5
Sand, coarse, clay, gray-green	46	1,034.5
Sand, fine to medium, arkosic, angular sand; blue and gray plastic clays and silts and a little coarse, angular arkosic sand in alternating hard and soft beds	15.5	1,050
Sand, coarse, angular, and blue-gray clay, with a little fine sand	28.5	1,078.5
Clay, blue silt and very fine sand	3	1,081.5
Clay, sandy, blue-green, and sand; hard streaks	47	1,128.5
Clay, sandy, blue-green, with sand	45.5	1,174
Clay, hard, blue-green to gray-green with very little sand	16.5	1,190.5
Clay, soft, plastic, blue-gray; occasional bits of coarse angular sand, and very fine, micaceous sand	14.5	1,205
Sand, very fine, micaceous, uniform, with blue-gray plastic clay and a large amount of leaves, wood, and seed pods	15.5	1,220.5
Clay, soft, plastic, blue-gray, and leaves with some fine sand	15.5	1,236
Clay, blue-gray, and gray silt with coarse, angular sand and a little fine sand	11.5	1,247
Silt, tight, green, non-plastic	18.5	1,265.5
Clay, soft, plastic, blue-gray, sticky	30.5	1,296
Sand, fine micaceous, very angular	15	1,311
Sand, micaceous; biotite in books but quartz grains rounded	16	1,327
Fresh, biotite-rich dioritic or more basic rock; possibly a cobble bed	28	1,355
Bedrock; very fresh, finely ground dark rock, rich in biotite	3	1,358

26/40-24R1. Perforated from 22 to 72 feet Altitude 2,260.4 feet.	Thickness (feet)	Depth (feet)
Sand, subangular to subrounded, poorly sorted, fine to very coarse	4	4
Sand, coarse, rounded, with calcareous cement	4	8
Sand, coarse; very fine gravel and a little black clay	1	9
Sand with less limy material	1	10
Sand with a little clay	1	11
Sand, coarse, uniform, angular to subangular with limy material	4	15
Sand, very coarse, angular, and very fine angular gravel	5	20
Gravel coarse, angular to well-rounded, with very coarse sand	10	30
Gravel, fine to medium.	4	34
Gravel, fine, and coarse sand	6	40
Gravel, fine, permeable.	4	44
Gravel, very fine, uniform, subrounded	4	48
Gravel, very fine, and coarse sand	2	50
Cobbles or tightly packed gravel	1	51
Gravel, fine	3	54
Gravel, very fine to fine	19	73
Clay, silty, and limy, cemented fine sand	7	80
Clay, green, finely sandy	10	90
Clay, blue-gray, crumbly to plastic, with much less fine sand and silt	10	100
Clay, sticky, plastic	10	110
Clay, silty, with shells	10	120
Clay	6	126
Clay, green, with finely sandy zones; semi-plastic to crumbly	2	128
Clay	2	130
Clay, green, plastic, with finely sandy or silty zones	17	147
Limestone, sandy, and poorly sorted sand	2	149

26/40-36A1. Perforated from 80 to 90, 107-127, 187 to 195, 240 to 260 feet. Altitude 2,247.2 feet.		
Caliche, hard, cemented	2	2
Sand, coarse, angular, with a little loosely cemented fine sand, fine gravel, traces of clay and caliche	11	13
Sand, fine to coarse, subangular to angular, and very fine gravel with some calcareous material	2	15
Sand, fine, hard, with calcareous cement	2	17
Sand, fine, soft, limy, with coarse angular sand and a little blue clay	2	19

26/40-36A1. continued	Thickness (feet)	Depth (feet)
Sand, very coarse, subangular to subrounded, and very fine gravel	5	24
Sand, medium to coarse	4	28
Sand, medium to coarse, with a trace of clay	5	33
Sand, medium, uniform, very angular, tight, hard	7	40
Sand, fine to medium, angular, with traces of blue clay	2	42
Sand, fine to medium, angular, hard	10	52
Sand, coarse, subangular, and fine angular sand	7	59
Sand, coarse, subangular, with oxidized grains	3.5	62.5
Sand, coarse, and fine gravel	2.5	65
Sand, coarse, with limy cement	2	67
Sand, coarse	3	70
Sand, medium, with limy cement	10	80
Sand, subangular, coarse, and very fine gravel, very loose	2	82
Gravel, cemented, hard	1	83
Gravel, very fine, subrounded to rounded, in part with limy cement	3	86
Gravel, fine, subangular, and medium to coarse sand	1	87
Sand, fine to coarse	3	90
Sand, very fine to coarse	12	102
Sand, very fine to coarse, with fine gravel	2	104
Gravel, fine to medium, hard, in part with limy cement	9	113
Sand, fine to coarse, with hard zones	11	124
Sand, coarse and very fine subrounded gravel	5	129
Clay, blue, silty to finely sandy, plastic	10	139
Clay, blue-green-black speckled	3	142
Silt, finely sand, gray, with a little gravel	8	150
Clay, silty, speckled, plastic, micaceous, with shells	10	160
Clay, green, silty	3	163
Clay and silty clay with some coarse sand and lime	10	173
Sand, fine to coarse, angular to subrounded, silty, and gray silty clay	14	187
Gravel, very fine to coarse, subangular, and some coarse sand	4	191
Sand, medium to coarse, limy fine sand, and blue clay	1	192
Sand, coarse, angular, and very fine gravel with a little silty clay	1	193
Sand, fine to coarse, with limy cement, hard	3	196
Sand, coarse, subangular to subrounded, and very finegravel	1	197
Sand, fine, angular, with a little lime and silt	8	205
Sand, medium, angular, hard	1	206

26/40-36A1. continued

	Thickness (feet)	Depth (feet)
Sand, fine, angular, coarsely silty	4	210
Sand, fine to medium, angular, with limy cement, hard	11	221
Sand, fine to coarse, angular to subrounded loose, with about 10% spherical to bean-shaped sideritic pellets in some zones	26	247
Sand, coarse, uniform, angular	13	260
Sand, coarse, and very fine gravel, in part cemented, subangular to subrounded	10	270

26/41-7G2. Perforated from 9.3 to 49.3 feet. Altitude 2,181.3 feet.

	Thickness (feet)	Depth (feet)
Sand, fine to medium, angular, loose, with some calcareous material	4	4
Sand, medium, uniform, rounded	6	10
Sand, poorly sorted, fine to very coarse, subrounded to rounded	7	17
Sand, fine to medium, subangular to subrounded, in part cemented	3	20
Sand, fine to medium, subangular to subrounded, with cemented fine sand and soft white calcareous material	3	23
Sand, fine to medium, subrounded, with numerous stained or oxidized grains	18	41
Sand, rounded, uniform, medium, loose, permeable	4.5	45.5
Transition zone	2	47.5
Bedrock	1.8	49.3

Table C III. Chemical analyses of water from test wells on Naval Weapons Center, China Lake, California

(Analyses in parts per million)

	25/40-33L2	25/41-28B1	26/40-1A2
Calcium (Ca)	-	-	0
Magnesium (Mg)	-	-	1.9
Sodium (Na)	-	-	5,400
Potassium (K)	-	-	64
Carbonate (CO_3)	-	-	2,430
Bicarbonate (HCO_3)	-	-	1,420
Sulfate (SO_4)	-	-	1,620
Chloride (Cl)	898	1,390	3,460
Fluoride (F)	-	-	-
Nitrate (NO_3)	-	-	-
Boron (B)	3.8	17	151
Sum	-	-	13,837
%Sodium (Na)	-	-	99
Specific conductance Micromhos @ 25°C	3,730	5,050	19,100
pH	-	-	9.6
Hardness Total as $CaCO_3$	205	200	8
Noncarbonate	-	-	0
Depth of well	22	162	198
Temperature (°F)	63	71	76
Date collected	3-4-54	3-10-54	3-9-54
Laboratory	USGS	USGS	USGS
Laboratory No.	10,796	10,797	10,795

	26/40-1A3	26/40-22P1	26/40-24R1	26/40-36A1	26/41-7G2
Ca	-	3.4	9.6	90	-
Mg	-	0.6	24	22	-
Na		407	228	483	-
K	-	7.1	18	24	-
CO_3	-	24	0	0	-
HCO_3	-	766	136	118	-
SO_4	-	23	83	62	-
Cl	19,500	152	314	875	1,440
F	-	4.0	-	-	-
NO_3	-	1.1	-	-	-
B	73	3.0	1.8	3.7	19
Sum	-	1,008	746	1,619	-

Continued

	26/40-1A3	26/40-22P1	26/40-24R1	26/40-36A1	26/41-7G2
% Na	-	98	77	75	-
$K \times 10^6$	52,700	1,690	1,430	3,060	6,580
pH	-	8.6	7.6	7.6	-
Hardness					
Total	22	11	122	315	11
N.C.	-	0	11	218	-
Depth	18	850	149	270	49
^oF	68	90	71	72	68
Date	3-17-54	2-23-54	3-9-54	3-8-54	4-5-54
Lab.	USGS	USGS	USGS	USGS	USGS
Lab. No.	10,801	10,623	10,800	10,799	10,798

Table C IV. Analysis of Fluids and Alteration Products in the Coso Thermal Area. (from, Austin, et al., 1971)

Analysis	Location						
	Devil's Kitchen, clear pool	Resort, shallow steam well	Resort, shallow well next to fault scarp	Resort, shallow well at old steam bath	Devil's Kitchen, siliceous residue	Devil's Kitchen, green siliceous residue	Resort, red mud
Constituent:							
Si	10-100	10-100	10-100	10-100	10-100	10-100	10-100
Fe	...	3-30	3-30	3-30	1.-1	1-10	1-10
Al	1-10	1-10	1-10	3-30	1-10	3-30	3-30
Ca	.3-3	.1-1	.1-1	1-10	.03-.3	.01-.1	.1-1
Mg	.1-1	.3-3	.3-3	.3-3	.01-.1	.003-.03	.1-1
Na	.03-.3	.3-3	.1-1	1-10	.01-.1	.03-.3	.1-1
K	.3-3	.1-1	.1-1	3-30	...	.3-3	.3-3
Mo	...	.0003-.003	.0003-.003	...	...	...	...
Zn	...	.003-.03	.01-.1	...	...	...	...
Sn	...	...	...	.01-.1	.001-.01	.001-.01	.003-.03
Co	...	...	...	.001-.01	...	.0003-.003	...
Sc	...	...	...	.0003-.003	...	.0003-.003	.003-.03
Y	...	...	...	...	...	.001-.01	...
B	.3-3	.03-.3	...	.1-1	.01-.1	.003-.03	.001-.01
Mn	.003-.03	.03-.3	.03-.3	.1-1	.001-.01	.0003-.003	.003-.03
Ag	...	...	...	...	...	...	.0003-.003
Cu	.003-.03	.01-.1	.003-.03	.01-.1	.003-.03	.003-.03	.003-.03
Ti	.03-.3	.1-1	.1-1	.1-1	.1-1	.3-3	.3-3
Sr	.01-.1	.003-.03	.003-.03	.003-.03	.01-.1	.03-.3	.03-.3
Ni	.003-.03	.0003-.003	.0003-.003	.003-.03	.001-.01	.003-.003	.001-.01
V	.001-.01	.001-.01	.001-.01	.001-.01	.001-.01	.003-.03	.003-.03
Pb	.001-.01	.001-.01	.003-.03	.03-.3	.001-.01	.01-.1	.003-.03
Ba	.003-.03	.01-.1	.01-.1	.01-.1	.01-.1	.3-3	.03-.3
Ga	.001-.01	.001-.01	.001-.01	.001-.01	.0003-.003	.003-.03	.001-.01
Cr	.0003-.003	.0003-.003	.0003-.003	.001.01	.0003-.003	.001-.01	.003-.03
Zr	.0003-.003	.003-.03	.003-.03	.003-.03	.01-.1	.03-.3	.003-.03
Be	.0003-.003	.001-.01	.0003-.003	...	...	...	...
Total dissolved solids, ppm	2,500	2,800	2,800	2,700	...	...	...
pH	1.5	4.5	4.5	...	...	...	...
Temp., °F	176	203	203	...	...	...	...

Table C-V. Recent Analysis of Waters at Coso Thermal Area. (from, Austin, et al., 1971)

Analysis	Location and date					
	22/39-7J1 Spring, 1960	22/39-4K5 Well, 1961	22/39-4K4 Well, 1961	22/39-4K3 Condensed steam from well, 1960	22/39-4K2 Spring, 1960	Coso No. 1 drilled well at 375 ft. 1967[a]
Constituent, ppm:						
SiO_2..........	326	306	326	203	202	50
Fe............	28	9.0	5.5	0.06	0.09	0.15
Al............	44	3.8	2.3	0.11	1.4	...
Ca............	18	44	28	17	98	72.8
Mg............	81	19	12	6.2	25	0.5
Na............	14	36	30	25	81	1,764
K.............	28	9.2	8.8	8.6	23	154
HCO_3..........	...	...	...	...	...	134.2
CO_3...........	...	...	...	...	...	84
SO_4...........	1,450	1,270	947	133	528	38
Cl............	...	375	275	1	6.5	2,790
F.............	0.9	0.6	0.4	0.2	0.8	3.70
NO_3...........	3.0	0.6	0.5	0.1	8.1	7.1
B.............	0.6	...	0.11	...	...	48
Mo............	1.7	...	0.8	...	...	0.0
Li............	0.1	...	0	...	...	...
PO_4...........	...	0	0.10	...	...	0.4
Br............	...	1.8	3.4	...	...	...
As............	...	0	0	...	...	...
Mo............	...	0.004	0.004	...	...	...
I.............	...	0.003	0.006	...	...	...
Cu............	...	...	...	...	...	0.0
Total dissolved solids, ppm...	2,260	2,060	1,070	443	1,030	5,744
pH............	2.2	1.2	2.1	4.5	4.0	8.9
Temp., °F........	206	115	173	201	78	240

[a] NWC analysis.

Table C VI. Geologic log and water analysis of samples from Coso No. 1 Drill Hole. (from, Austin et al., 1971)

Only one shallow test has been drilled here so details are lacking for depths beyond a few tens of feet in exposed granites and beyond a depth of 375 feet in alluvium covered granites.

Quarternary alluvium	185 feet
Weathered Cretaceous granite	24 feet
Altered granite	65 feet
Hydrothermally altered granite	5 feet
Slightly altered granite	20 feet
Heavily fractured altered granite	25 feet
Hydrothermally altered granite with clay	10 feet
Altered granite	40 feet
Total depth	375 feet

Sample 1 was taken from the well discharge (clear water) at completion of drilling after blowing the well with compressed air for over 1 hour. Samples 2 and 3 were taken after the well was idle for 7 months. Sample 2 is from the first and third bailer, and Sample 3 from the 13th and 14th bailer. All water from depth of 375 feet.

Data	Sample No. 1	2	3
Data:			
Sample taken	27 Jun. 67	Mar. 68	Mar. 68
Analysis	12 Jul. to 3 Aug. 67	16 Apr. 68	16 Apr. 68
Temp., °F	240	287	287
Constituent, ppm:			
Ca	72.8	359.0	74.4
Mg	0.5	0.6	1.0
Na	1,764	2,808.0	1,632.0
K	154	172.0	244.0
CO_3	84	50.4	77.4
HCO_3	134.2	0.0	0.0
SO_4	38	216.0	52.8
Cl	2,790	3,681.0	3,042.0
NO_3	7.1	trace	trace
NO_2	...	negative	negative
SiO_2	50	27.0	154.0
F	3.70	1.60	2.20
B	48	57.42	71.60
Fe	0.15	...	...
Mn	0.0	...	...
PO_4	0.4[a]	0.23	0.88
Cu	0.0	...	...
OH	...	76.2	1.7
Br	...	4.67	2.55
As	...	0.94	7.50
NH_4	...	trace	trace
Hg	...	1.4	0.0
Synthetic detergents, apparent ABS	0.290	...	...
Total dissolved solids, ppm	5,744	6,894.0	5,228.0
pH	8.9	9.8	8.5
Analytical laboratory	Navy	Hornkohl	Hornkohl

[a] Ortho.